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This dissertation has been prepared for possible use by the United States Military. The format and style used is consistent with Air Force Pamphlet 13-2, 2 January 1985, *Tonque and Quill* and with the styles used at the Air Force Institute of Technology at Dayton, Ohio. The dissertation will be submitted in its entirety to the Air University Library, Maxwell AFB, Alabama 36112-5001, for retention and filing.

ABSTRACT

This research reviewed 16 environmental cleanup Records of Decision (ROD) from 12 different Air Force bases to determine the amount of savings possible from land-use restrictions. Land-use restriction is defined as keeping the use of the land and/or groundwater in its present form. The savings is obtained by comparing the cost of the land-use restriction alternative to the cost of the remedy selected in the ROD. A total savings of 13 percent was obtained from all 16 RODs. The 13 percent is considered a conservative estimate. The savings at individual sites ranged from zero to 92 percent.

The research methodology employed also surveyed Air Force base-level environmental managers on possible cost savings measures. The 64 survey respondents ranked "Realistic Risk Assessments" first and "Land-use Restrictions" second among the five cost-savings measures ranked. The survey respondents estimated Realistic Risk Assessments as having a 26-40 percent savings potential and Land-use Restrictions as having a 16-25 percent savings potential.

The author examines CERCLA and SARA laws for compatibility with land-use restriction and recommends a procedural change to Exposure Assessments under the CERCLA process to provide decision makers with sufficient information to adequately consider land-use restrictions in selecting an appropriate remediation alternative.

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I. INTRODUCTION

A. BACKGROUND

The background of how the United States came to embrace a national cleanup of hazardous waste sites is quite lengthy. This section is designed to give the reader a quick background on this process from which to base an understanding of the rest of the research.

In 1952 sanitary/civil engineers at the University of Southern California, in performing research for the State Water Pollution Control Board, analysed dirty water that was issuing from municipal ash and garbage dump sites. The term "leachate" was coined to refer to this dirty water. At that point in time, the majority of the nation's wastes were disposed of in "dumps". Dumps are unengineered, undesigned, uncontrolled disposal areas. It became increasingly more apparent that water was being polluted by these disposal sites. In 1965, the Federal Solid Waste Disposal Act was passed. It provided financial assistance to states for planning and establishing solid waste management programs, in most states for the first time (1:299). This was to help control the disposal of solid waste across the country. In 1976 the Resource Conservation and Recovery Act was passed, defining solid wastes, special wastes, and hazardous wastes. Among other provisions, it began the first national program to regulate the generation, transportation, storage, treatment, and disposal of hazardous waste (2:5). In the summer of 1978, a failed disposal site in upstate New York, near Niagria

Falls, called Love Canal, received national attention. In the 1940s and early 1950s hundreds of tons of chemical wastes, many of which were liquids, were deposited in an abandoned canal in the area. This was considered an acceptable practice at the time. The land was donated to the City and subsequently developed into unauthorized residential housing, in contravention with a legal covenant with the previous industrial owner. Toxic chemicals from the site over the years were released to the air and groundwater exposing the residents of the Love Canal area to these chemicals. Testing in the area confirmed heavy chemical contamination in the air, water and soil. A 1978 preliminary health survey of over 100 residents of Love Canal showed an increase in health problems including urinary tract and central nervous system disorders, and adverse reproductive outcomes such as miscarriages, stillbirths, and birth defects. In August of 1978 the State of New York declared a health emergency at Love Canal (3:23).

In this same period of time comparable sites such as the Valley of the Drums in Kentucky, the Stringfellow Acid Pits in California, and the Seymour Recycling Facility in Indiana also received national attention (2:7). Something had to be done, there were hundreds if not thousands of such sites in the United States, posing an unacceptable risk to society.

To respond to the situation, threats of uncontrolled hazardous waste sites (UHWS), Congress enacted the Comprehensive Environmental Response, Compensation and

Liability Act (CERCLA) in December 1980. This legislation was designed to resolve the issue of abandoned, uncontrolled, inactive hazardous waste sites (2:7). The program, commonly referred to as Superfund, was initially authorized for a five-year period. The effectiveness over the first five years was the topic of considerable debate. The debate between the Administration and Congress on the success of the program and the direction it needed to take in the future lasted through 1985 to 1986. It was culminated in 1986 with the enactment of the Superfund Amendments and Reauthorization Act (SARA). SARA provided a preference for the selection of "permanent" treatment at sites. It also required cleanups to be in compliance with State and Federal standards. This is referred to as compliance with "applicable, relevant, and appropriate regulations (ARARs)". SARA was reauthorized through FY 1994 and expired on 1 October 1994. The administration's proposal for the reauthorization of SARA has been submitted to Congress and the debate on this reauthorization is currently underway.

CERCLA as ammended (1986) has four major components. These components are:

1) Establishes a fund to pay for investigations and remedial actions at sites where the responsible parties cannot be found or will not voluntarily contribute (Superfund).

2) Establishes a priority list of abandoned or inactive hazardous waste disposal sites for remediation (National Priority List [NPL]).

3) Establishes a mechanism to determine the appropriate action to take at abandoned or inactive hazardous waste disposal sites (the National Contingency Plan [NCP]).

4) Establishes a system of liability for potentially responsible parties (PRPs) to clean up, or pay to clean up, sites (2:10).

The system of liability for cleanup set up under CERCLA is strict, joint and several. Strict liability is liability without fault. If a site is found to pose a threat to human health or the environment, the responsible party is liable for the costs of cleanup regardless of any argument. Joint and several liability is that each person can be held liable for either a portion or the entire cost of site cleanup. In other words, if a party contributed any wastes at a site, that party can be held liable for all costs associated with the cleanup (2:11).

A hazardous waste site needing remediation will fall under one or the other of these two major categories of legislation, RCRA or CERCLA. The remediation of sites are then classified as RCRA Corrective Actions or CERCLA (Superfund) emergency responses or remedial actions. CERCLA applies if the site is abandoned, uncontrolled, or inactive; RCRA applies if the site is owned or operated by an identifiable person or corporate entity. Due to the number of sites contaminated by leaking underground storage tanks, a separate state-managed program (Underground Storage Tanks [UST]) was initiated by Congress in 1984, as part of the Hazardous and Solid Waste Amendments (HSWA) to RCRA, to handle such remediation.

The CERCLA site cleanup process begins with the identification of a suspected hazardous waste site and goes

through the completion of the remedial action to the operation and maintenance of the site. These steps are shown in Figure 1. Once a site is identified it is submitted to the CERCLIS, EPA's computerized inventory of potential hazardous waste

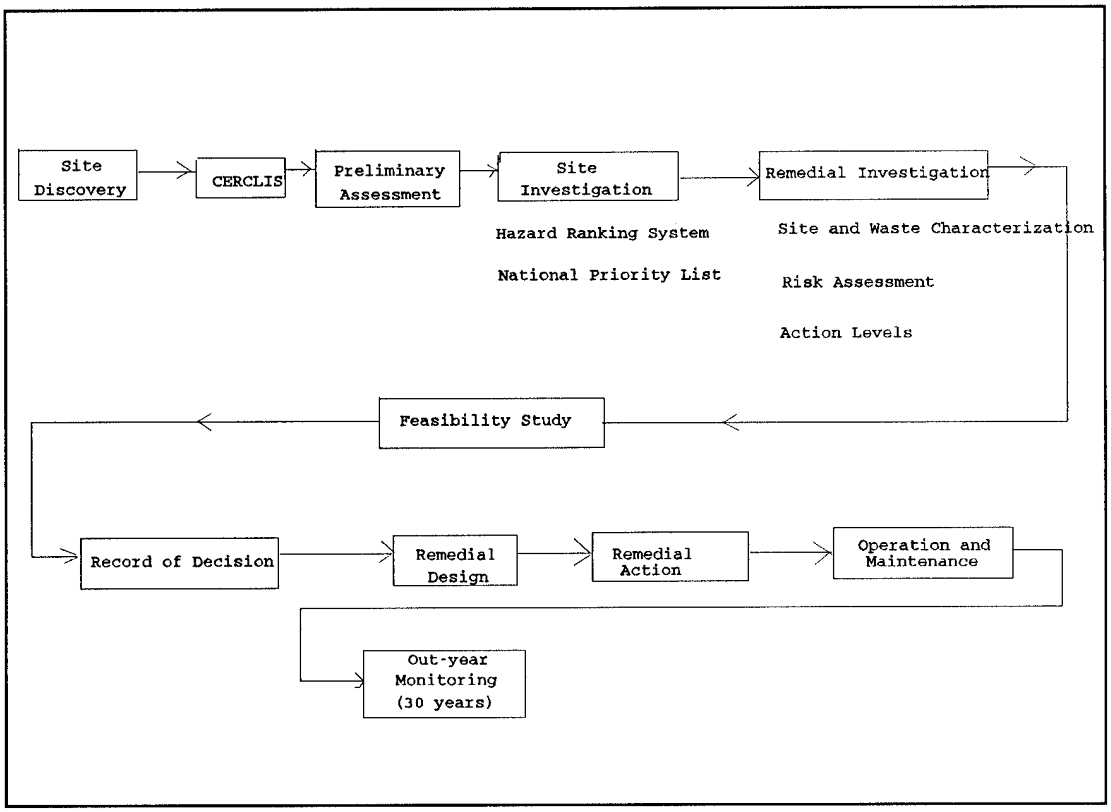


Figure 1, CERCLA Process

sites. Once entered on the list the site is never removed, as a safeguard to a future rediscovery. This allows for maintenance of a master list of all sites, false-detected, contaminated, and those closed after remediation. This prevents the same site from being repeatedly discovered and submitted.

Once the site is entered on CERCLIS a Preliminary Assessment (PA) is ordered. The PA is a limited-scope investigation performed by the State or EPA-Region on every CERCLIS site. The PA is designed to distinguish between sites that pose little or no threat to human health and the environment and sites that require further investigation. (4:2)

If the PA indicates a need for further investigation, a Site Inspection (SI) is performed. During the SI, investigators collect samples to identify the hazardous substances present and whether they are being released to the environment. The objective of the SI is to identify sites posing immediate and/or on-going health or environmental threats. The SI also identifies which sites have a high probability of qualifying for cleanup funding by placement on the NPL. (4:2)

At the conclusion of the SI, the EPA or State environmental agency, whichever is taking the lead, applies the Hazard Ranking System (HRS) to derive a quantitative site score. A site with a HRS of 28.50 or greater (of a maximum of 100 points) is eligible for nomination to the NPL. (4:4)

At the end of the SI and computation of the HRS, a determination is made that either the site requires further investigation or that the site should receive a "no further remedial action planned" (NFRAP) recommendation (4:4). Sites that warrent further study, including those on the NPL, receive a remedial investigation (RI). The RI is a field

investigation to characterize the nature and extent of contamination at the site. The results of the RI can be grouped into three areas; 1) Site and Waste Characterization, 2) Risk Assessment, and 3) Remedial Action Objectives and Action Levels for achievement of cleanup. To arrive at the Risk Assessment a specific evaluation process is followed. This process is shown in Figure 2. One of the components of

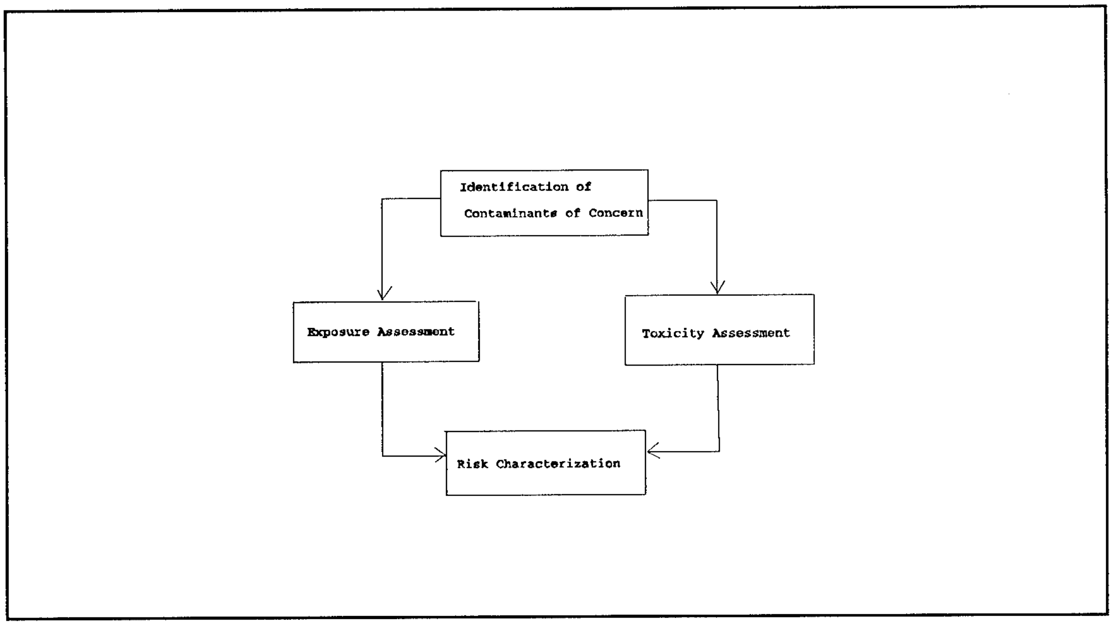


Figure 2, Risk Assessment Process

the Risk Assessment is the Exposure Assessment. An outline of the Exposure Assessment is shown in Figure 3. The Exposure Assessment identifies potential exposure pathways and routes, characterizes potential receptors, and estimates the expected exposure levels. This process also determines if activities associated with current land use are likely to be different under an alternative <u>future</u> land use (5:6-7). EPA guidance

states that determining expected future land use does not require extensive analysis but instead boils down to the application of good engineering judgement. Generally residential land use is the most conservative and creates the greatest potential exposure. A default assumption of future residential land use is often applied to the Exposure Assessment if no land use restrictions are currently in place to prevent future residential land use. This assumption of future residential land is used to develop a maximum exposure scenario that is used to characterize the risk to human health. (5:6-5)

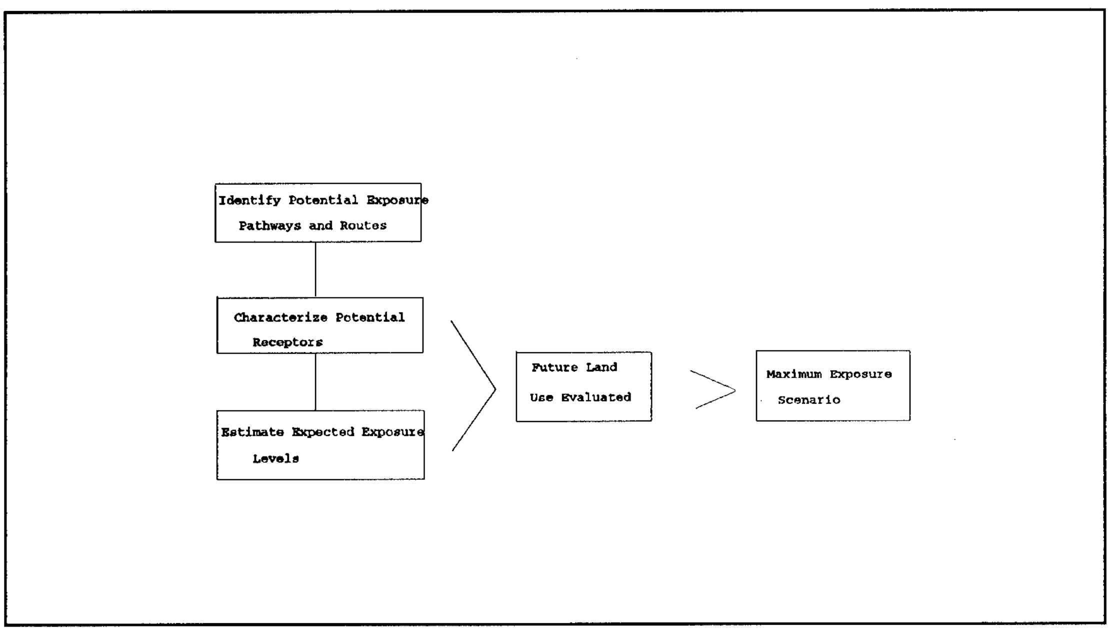


Figure 3, Exposure Assessment Process

After the RI process characterizes both site and waste, the risk to human health and the remedial action objectives are determined, the Feasibility Study (FS) then evaluates

applicable alternatives and their component technology options to be considered in selecting the final remediation action(s) (4:4). The FS is based on the data collected during the RI and is usually begun before the RI is concluded, in order to allow for additional supporting tests and data collection as required for consideration by the engineers conducting the FS.

The current Feasibility Study process uses nine evaluation criteria provided in SARA to analyze Remediation Alternatives. The nine criteria are:

1) Overall protection of human health and the environment
2) Compliance with ARARs (unless waiver applicable)
3) Long-term effectiveness and permanence
4) Reduction of toxicity, mobility, or volume through the use of treatment
5) Short-term effectiveness
6) Implementability
7) Cost
8) State acceptance
9) Community acceptance (6:6-4)

In addition to the preference for permanence stated in the criteria, Section 121 of CERCLA, states a strong statutory preference for remedies that are proven as highly reliable and which provide assurance of long-term protection. This preference includes:

- A preference for remedial actions that employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants as a principal element

- Offsite transport and disposal without treatment is the least favored alternative where practicable treatment technologies are available
- The need to assess the use of permanent solutions and alternative treatment technologies or resource recovery technologies and use them to the maximum extent practicable (6:1-4)

The permanent technologies deal with the treatment or distruction of the hazardous waste. Containment technologies deal with isolating the waste from exposures that will effect the public's health. In general, permanent technologies are usually more expensive than traditional containment technologies. Thus, the cost of remediation can become a minor factor when considered along with the other factors that give preference to higher cost methods of removal or treatment.

After all the data and site studies have been evaluated and converted to various Remedial Action Options, the EPA Regional Administrator selects a Final Remedy and prepares a Record of Decision (ROD). The ROD supports the selection of the final remedy by documenting the considered facts, analyses, and policy demands and constraints. (4:4)

The next step in the process is Remedial Design (RD). The purpose of the RD is to convert the Final Remedy into a design that can be implemented. The final design package will typically include design plans and specifications, a construction cost estimate, draft operation and monitoring plan, and a quality assurance program plan (QAPP). (4:57)

The next step is construction of the Remedial Action (RA). The RA is the implementation of the plans and specifications prepared in the RD. It starts with the award of a contract or the start of construction and culminates with the acceptance of the final project. (4:59)

Many sites will require Operation and Maintenance (O&M) of equipment, structures or earthwork after the Remedial Action is installed. This is the final step in the CERCLA process. Appropriate plans for these activities will have been identified in the FS and ROD. (4:59)

There are two major areas of potential cost savings in the CERCLA process. The first occurs in the Remedial Investigation. There is a possibility that the chosen cleanup levels called for in the remedial action could be reduced in accordance with an alternative land use representing inherently lower acceptable level of risk as determined by a revised Risk Assessment. The second occurs in the Record of Decision and is the selection of cost-effective cleanup technologies. This decision is based on the information contained in the Feasibility Study. One method of reducing the cleanup level required, thus reducing cost without causing an increased risk to human health, is to restrict human access, and to inherently limit exposure to the remediated site. Choosing an alternative future use of the site as something other than residential occupancy (most conservative) will inherently reduce human exposure. If residential land use is a very real possibility, land-use restrictions or deed

restrictions can be used to prevent this alternative. Land-use restrictions specified in deeds of title are institutional controls not normally considered until the Feasibility Study. This occurs after the Remedial Investigation and Risk Assessment have already considered the future land use and the maximum exposure scenario. Selection of preferred cleanup technologies in the ROD is based on the nine evaluation criteria and the evaluation of alternatives conducted as part of the FS. The criteria, by giving preference to permanent remedies, places land-use restriction or deed restrictions, which are considered non permanent remedies, at a disadvantage. Thus, cost reduction by restricting future land use is not explored in the Risk Assessment process or given adequate consideration in the Feasibility Study.

RCRA and CERCLA laws and programs apply to government facilities as well as those of the private sector. To manage and fund the cleanup of military hazardous waste sites separately from Superfund, the DOD created the Defense Environmental Restoration Account (DERA) and its operational component, the Defense Environmental Restoration Program (DERP) in 1984. DERA was initially funded in 1984 at $159 million (7:26). Part of DERP is the military Installation Restoration Program (IRP). IRP is the mechanism DOD uses to cleanup hazardous waste sites. It provides a structured but flexible approach for identifying, evaluating, and cleaning up sites for which the military is responsible for having created. The program is implemented subject to and in a

manner consistent with CERCLA. Military IRP activities do not receive Superfund monies whether listed on the NPL or not, but instead must use DERA or other DOD funds for implementing the IRP. IRP is essentially the same process as that of CERCLA, with some additional administrative requirements (8:1-3). The 1993 fiscal year Department of Defense environmental budget included nearly $1.2 billion for IRP cleanup of hazardous wastes sites. An additional $444 million was earmarked to cleanup at military bases that are scheduled to close (9:30). A list of Air Force bases in the United States recently closed or scheduled to be closed is in Appendix A.

The American military is currently in a drawdown posture. During the drawdown, as a cost savings measure, military bases are selected for closure. Closings were announced in 1988, 1991 and 1993 (8:11). The closings announced in 1993 included 35 major and 95 smaller installations throughout the DOD (10:5); the total count is now at 255 DOD installations to be closed. So far the Air Force has closed or is scheduled to close a total of 27 bases in the United States (11:14). There is another round of Congressional closing hearings scheduled to begin the summer of 1995. As these installations are closed they are transferred to the local community or private sector. Prior to the transfer the military is responsible for completion of all necessary environmental cleanup actions at each property.

B. PROBLEM STATEMENT

As the military drawdown is occurring the military budget is also decreasing. The military base closures were initiated as a cost savings measure. The cost of environmentally remediating these bases prior to transfer to the community has been extremely large. These costs and other environmental related costs are causing the DOD environmental budget to significantly increase. DOD's newest environmental budget is more that $50 billion over the next five years. $5.7 billion is allocated for FY95. Of the $5.7 billion, $2.2 billion is for cleaning up hazardous and toxic wastes (12:11). Environmental costs can not continue to rise while the budget decreases. Something must be done. With the federal government looking to reduce the deficit and government spending, the competition for governmental financial resources is going to be keen. No longer will there be the luxury to fund programs that are excessively costly. The new Republican-controlled Congress has already began to look at the DOD environmental programs as a source of Defense budget reductions without impacting the national defense posture. There will have to be decisions made based on which programs generate the most benefits for the cost. Richard J. Mahoney, chairman and CEO of Monsanto Corporation (1993) put it this way.

> People want to know, even with the environment, what we are getting for our money, ... we are beginning to recognize that we do have finite resources and one must make choices (13:30).

Federal spending on hazardous waste cleanup has grown 65-fold, from $183 million in 1984 to about $12 billion for 1994 (14:8). The benefits derived from these costs must be considered. The costs of environmental cleanup cannot be allowed to continue in uncontrolled increase.

With more installations being closed, the environmental cleanup of those installations may become so expensive that the military cannot afford cleanup prior to property release to the community market. According to former Representative Dave McCurdy (1993), past chairman of the House Armed Services Military Installations and Facilities Subcommittee,

> There will be decisions on certain select bases that it may be cheaper to keep the doors technically open instead of going through the process of cleaning up [the bases] to turn them over (15:54).

The cost of the cleanup at the Philadephia Naval Base alone is estimated at $1 billion (15:54). McCurdy further stated that "the soaring cost is threatening to halt the process of closing bases and turning them over to commercial developers". That would mean no new jobs created to replace those lost when a base closes. What was originally viewed as a cost savings measure may instead cost additional funds and cause loss of jobs.

California politicians are deeply concerned about the base closure and reuse process. The state will suffer 69 percent of the personnel cuts due to the 1988-93 base closure actions. With the environmental cleanup at the closing California bases estimated at $2.5 billion, the State is

worried that closed bases may sit idle with disastrous economic consequences to surrounding communities. (16:12)

A 1970 study on the economic impact of base closures on local communities, examined bases closed after the Vietnam war. The study found:

> The reduction of 100 civilian personnel can be expected to result in the loss of 258 jobs in the service sector within six months. Similarly the transfer of 100 military personnel from any operational base can be expected to result in the loss of 66 service jobs in the local economy. (17:268)

This shows the closure of military bases can have a significant impact on the local community.

President Clinton has promised a speedier environmental cleanup of military bases to be closed. This is an effort to restore jobs lost from the base closures as quickly as possible. This "fast track" cleanup program must still comply with CERCLA and IRP guidelines. The program allows cleanup steps to be done concurrently rather than sequentially and under the program DOD won't be fighting any cleanup liability but will accept such costs. This program is a time saving measure and not a cost savings measure. (10:5)

C. SIGNIFICANCE/JUSTIFICATION FOR STUDY

The Department of Defense has estimated that 7,300 present or former military sites will require some form of remediation over the next twenty years (18:1). A study at the University of Tennessee, Waste Management Research and Education Institute estimated that $30 billion dollars would be needed to handle this remediation under current

Environmental regulations and policies. An additional $240 billion of federal money would be needed to handle the Department of Energy sites (19:16). This means $270 billion of taxpayer's money will be needed to cleanup federal facilities.

The Department of Defense is legally responsible for paying for all cleanup work at closure installations. There is increasing concerns that funding shortfalls will lead to delays in base cleanup and subsequent reuse. In January 1994, Congress rescinded $507 million in base cleanup funding to provide disaster assistance following the Northridge, California earthquake. (16:14) This demonstrates that tough decisions have to be made on the amount of money necessary and available to fund base cleanups.

The White House in an effort to take control of the cleanup costs and strategy for federal facilities created an interagency group chaired by the chief of the White House Office of Environmental Policy, Kathleen McGinty and the deputy director of the Office of Management and Budget, Alice Rivlin (14:1). The group is to develop a strategy for the oversight and coordination of federal facility cleanups.

Co-chair of the group Alice Rivlin, in testimony to the Senate Governmental Affairs Committee, mentioned the need to consider future land use of contaminated sites in decision-making. She further stated:

> Not all of them [contaminated sites] are going to be used for residential purposes or places where you might want to put a day care center. It is neither feasible nor affordable to clean all of them up to residential standards (14:8).

The House Appropriations Committee hoping that taking into account future land use in future decision-making will reduce cleanup costs chopped $593 million (26%) from the Defense Environmental Restoration Account for fiscal year 1994. The committee supports the view of the Deputy Undersecretary of Defense for Environmental Security, that cleanup will be cheaper and quicker if matched to future use (20:1).

Will taking into account future land use actually save over 25% of the environmental restoration costs on military installations? Is this possible under current CERCLA and IRP procedures and guidelines? These are questions that have not been thoroughly answered yet the funding has already been reduced based on this concept.

D. RESEARCH OBJECTIVES

In view of the extreme need to accomplish the already initiated restoration program, the objectives of this research are to:

1) Determine if environmental remediations at Air Force closure installations can be accomplished more cost effectively by taking into account future land uses

2) Be able to quantify the extent of the cost savings

3) Determine if these savings are possible under current CERCLA and IRP regulations and guidelines

4) Determine an appropriate technique to consider future land use controls prior to determining appropriate action levels

This research hopes to provide groundwork for DOD to consider future land use and possible land-use restrictions as the essential cost-saving part of the environmental cleanup at Air Force closure installations. Hazardous waste remediation technologies and requirements seem to be constantly changing. The requirements may change in the future. However, this dissertation research will help future researchers and managers better understand the complex decisions of resource allocation regardless of regulatory requirements and hopefully allow them to effectively allocate the available limited resources for hazardous waste sites cleanup in a cost-effective manner while protecting the public's health.

E. RESEARCH QUESTIONS

In order to successfully reach the research objectives, the following research questions must be answered:

1) What are the potential cost savings to Air Force hazardous waste remediation costs by restricting future land use to current land use?

2) Are the cost savings significant enough to implement?

3) Can the future land use restriction savings be realized under current CERCLA and IRP procedures?

4) What procedural or regulatory changes are necessary, if any, to implement future land use restriction criteria?

F. SCOPE AND LIMITATIONS

There are certain limitations under which this research is operating. The first is the time factor. The first list of base closures in the military drawdown were announced in 1988. The process of closing bases and conducting the

environmental cleanup, then transferring them to the local community is lengthy. The CERCLA process from start to finish rarely takes less than seven years and can take as long as a decade (21:76). This means that a large amount of the information on the actual cleanup decisions and costs are not yet available for analysis. This restricts the analysis to those installations for which the information is available.

Sufficient research data are available, however, in the form of Records of Decision on cleanup remedies already selected for applicable sites. The normal source for obtaining RODs is through the National Technical Information System (NTIS) operated by the Department of Commerce. All government research reports and standard regulatory documents are submitted to NTIS which then catalogs and publishes a continuously-updated documents listing. These documents can then be openly purchased through NTIS. The time lag from when the ROD is completed until it is available to purchase through NTIS can be a year or longer. Rather than purchase the available RODs from NTIS, the RODs for this research were obtained directly from the closure base. The research information is only as good as the information contained within the ROD. Since the ROD is a summary of information contained in other documents it is possible that pertinent information may have been overlooked or omitted. The rationale and factors considered in the selection of the remedy are often not thoroughly explained. This leaves one to make assumptions and/or read between the lines.

G. ASSUMPTIONS

Throughout this research the term "land-use restriction" will be used. In environmental remediation land-use restrictions are used to prevent or reduce future human or environmental exposure to contaminants remaining on the site. Deed restrictions are the common way of implementing land-use restrictions. An example would be a deed restriction that permanently prohibited the excavation or subsurface construction on a site with hazardous materials remaining after the remedial work is completed. The advantage of land-use restrictions is that they are inexpensive, provide protection of human health and are relatively simple to implement. The problem with land-use restrictions is that they are not considered a permanent treatment technology and such permanence is preferred under CERCLA.

For the purpose of this research, land-use restriction will mean limiting the future use of the land to its current use. As an example, if the land is currently used for industrial purposes its future use will be limited to industrial purposes and will not be allowed to be used for residential use. Land-use normally falls into the following major categories:

- Residential
- Industrial
- Agricultural
- Recreational

At Air Force installations the land-use areas are delimited in the base land-use or community plan. The type of base facilities that are included in each category are:

Industrial - Flightline areas, hangers, supply warehouses, maintenance shops, civil engineering shops, wastewater treatment facilities, fuel storage areas

Recreational - Ballfields, lakes, golf courses, picnic areas, FAM camps

Agricultural - Any base areas used for grazing or leased for commercial production

Residential - Base family housing, personnel dormitories

In general the land-use can be ranked as follows, with (1) being the lowest level of contamination permitted and (4) the highest level permitted without impacting human health.

1. Residential
2. Agricultural
3. Recreational
4. Industrial

This is a very general assumption with the actual contaminated level dependent on individual site characteristics, the media, and the exposure pathways.

For the purpose of reuse of the closure installation the land-use restriction would not prevent a lower ranking category from being used for a higher ranked purpose. As an example, land-use restriction would not prevent a current public-use area to be designated for a future industrial use. It would however, prevent the industrial area from being designated as a public-use area. The land-use restriction will be in the form of a deed restriction that will accompany the land in all subsequent transfer transactions.

A basic assumption of this research is that allowing higher risks to human health or the environment than the current policy allows is unacceptable. While the basis of the research is to determine if hazardous waste remediation can

sustain cost savings by restricting future land use, it is not looking at any concept whereby risks to the public health are allowed to increase as a means to save money. Those levels of risk to public health that are currently considered acceptable are herein incorporated as the acceptable level for this research. Accepting this level of risk does not mean the research accepts or agrees with current methods of determining the level of risk.

The acceptable level of risk varies from State to State. The EPA uses a range of 10^{-4} to 10^{-6} as an acceptable range for an increase in carcinogenic risk. The State of Maine, uses a 10^{-5} as an acceptable level and the State of California usually uses a value of 10^{-6} as the acceptable level. The acceptable level in this research is the level determined to be acceptable by the State in which the site is located. Most all states use a Hazard Index of 1.0 as the acceptable level for noncarcinogenic risks.

In computing the risks, two values are commonly used. The first is the Reasonable Maximum Exposure level or RME. This value is used to determine the maximum risk to public health. The other value is the average exposure value. This value is used to determine expected or average the risk to public health. The RME is the conservative approach and the one called for in EPA regulations. In this research the RME method will be the acceptable method for determining the risk to public health.

H. ORGANIZATION OF DISSERTATION

This dissertation consists of five sections. Section I provides an overview of the problem, its significance and also presents the intended objectives of the research. Section II views other research conducted in the area and underscores the need for action. Section III describes the methodology to conduct the research. In addition it explains the cost estimating software that will be used in the research. Section IV shows the analysis of the Records of Decision and the findings and results gleaned from that analysis. Section V summarizes the conclusions drawn from the analysis conducted in Section IV and includes recommendations and suggestions for further research.

II. LITERATURE REVIEW

A. COSTS OF HAZARDOUS WASTE CLEANUP

Generalizing the costs associated with environmental remediation and hazardous waste cleanups is very difficult. Each report seems to consider different components or adjusts the cost factors in different manners. The goal of this portion of the report is to give the reader, based on the literature, an indication of the magnitude of costs involved in hazardous waste cleanups and the direction in which the costs are heading.

A 1989 report to the Coalition on Superfund on the benefits and costs of superfund cleanups classified the costs of cleanup as the compensating payments to individuals supplying:

- Labor
- Land
- Capital (22:12)

This was done as a simplified method of determining cleanup costs in lieu of using the following categories:

- Cleanup Expenses
    - Planned
        - Onsite
        - Offsite
    - Unplanned
- Environmental and health damage from residual contamination and cleanup activities
- Environmental and health damage from technology failure
- Transaction costs
    - Government personnel time and expenses
        - Litigation

    -- Project management
    -- Other
- PRP personnel time and expenses
    -- Litigation
    -- Other
- Consultant studies
- Other (22:12)

This categorization would be much more difficult to calculate than just the labor, land and capital. It is also pointed out in the report that this list is not all-inclusive. As an example, if a manufacturing firm has to spend money on a Superfund cleanup the product price may go up, consumers would have to pay more to offset those higher prices. Higher prices, reduced incomes or other adverse effects that may accompany a cleanup effort all can be considered as costs of the cleanup. (22:12)

The benefits of the cleanup are classified in the report as:

- To Individuals
    - Health
        - -- Mortality
        - -- Morbidity
        - -- Other
    - Anxiety
    - Aesthetics
    - Loss of independence
    - Other

- To Production
    - Crops/Forests/Fisheries
    - Water-Using Industry
    - Municipal Water Supply Authorities

- To Economic Assets
    - Materials (corrosion)
    - Property values

- To Environmental Assets
    - Use
        - -- Recreation
        - -- Other

- Nonuse (existence)
- Reduced Waste Creation (deterrent effect)

The 1989 report did not attempt to quantify either costs or the benefits, but instead recommended a benefit-cost approach for dealing with cleanups. While the report explains that a quantitative benefit-cost analysis for cleanup operations can be difficult, it concludes that a benefits versus costs comparison should be part of every removal and remedial action decision (22:63). The report states:

> With the average cost of a remedial action under SARA estimated to be $25 million, we simply cannot fail to ask whether the good that will be done is in some sense commensurate with that cost, CERCLA not withstanding, there is nothing untoward about asking whether society is getting its money's worth out of Superfund cleanups, or any action, for that matter (22:63).

The report also points out that CERCLA calls for "permanent" remedies to be used at waste sites. This may run contrary to the traditional benefit-cost analysis approach of civil construction. What if 90 percent of the total risk at a site can be alleviated with only 30 percent of the cleanup costs? A benefit-cost approach might help guide a decision to save the 70 percent of the resources for use at other sites. This approach is not possible under CERCLA's current permanent remedies approach. (22:63)

Dr. Paul R. Portney, vice president and senior fellow at Resources for the Future, an independent, nonpartisan research and educational organization concerned with natural resources and the environment, conducted a 1992 study entitled "The

Economics of Hazardous Waste Regulations". In the study he estimated that by the year 2000, total annual compliance costs for all environmental programs will reach $170 to $185 billion, and that hazardous waste costs would be about $32 billion of that total. He stated that these large outlays will make it increasingly difficult for affected firms to make the necessary investments in the new plants and equipment necessary to compete effectively in international markets. (23:11)

John S. Larsen, corporate vice president, Office of the Environment, at Weyerhauser Company (1992) stated that the annual compliance cost of RCRA and CERCLA at Weyerhauser was $25 million in 1990. This equated to about 5 percent of earnings before taxes. Weyerhauser estimates continuing annual costs of between $15 million and $25 million for the next decade (23:29).

RCRA and CERCLA compliance costs for American industry was $12 billion in 1990. Dr. Portney's report compares the U.S. policy for cleanup of waste sites with a proposed European Community (EC) directive. The EC directive, while the stiffest of the European environmental policies, still falls far short of the U.S. policy. The EC directive is limited to only future waste disposal actions by firms and exempts waste generators from liability if they use a permitted disposal facility. Perhaps the most interesting aspect of the EC directive is that it includes a benefit-cost test. Cleanups are not required so long as the cost of the

cleanup exceeds the environmental benefit that will result and so long as other measures are available (23:17). The results is that U.S. firms are not dealing with a "level playing field" when competing in international markets against other international firms. The report recommends that Superfund and RCRA be modified to allow remedies that can be tailored to the risks to the population in lieu of the "permanent" remedies currently called for in the legislation. The report states:

> But there are many sites where cleanups will cost tens or hundreds of millions of dollars, indeed, at several of the DOE facilities, and some private sites as well, the cost of "permanent" remedies will probably eventually exceed $1 billion. It makes little sense at these sites to assume that such expensive remedies will automatically produce risk reductions sufficient to justify such expenditures (23:20).

The cost of environmental programs in the U.S. could effect the ability of U.S. firms to compete in international markets or mean the closure of U.S. facilities and relocation to other countries. In this case the regulatory costs would take the form of lost jobs (23:19). Is the solution to this problem reducing the U.S. environmental laws or pushing for more reaching international environmental laws?

The University of Tennessee's Waste Management Research and Education Institute, created and sponsored by the U.S. Department of Energy, conducted a study looking at the resource requirement necessary to accomplish the nation's hazardous waste remediations. The results are shown in Table I. The cost to the nation would be approximately $752 billion. This cost is the cost required under current RCRA

Table I, Resource Requirements Current Policy

Remediation Authority	Plausible Lower Bound	Best Guess	Plausible Upper Bound
		($ Billions)	
National Priority List	106	151	302
RCRA Corrective Actions	170	234	377
Underground Storage Tanks	32	67	*
Department of Defense	*	30	*
Department of Energy	110	240	*
State/Private Programs	*	30	*
TOTAL	478	752	1,046

* The estimate is not thought to differ from the Best Guess

(19:16)

and CERCLA policies. The study also considered what would be the resource requirements if a more stringent policy was enacted requiring cleanup to allow future unrestricted use of sites and groundwater (no land use or deed restrictions). The results are shown in Table II. The nation's cost under this policy increases to $1.177 trillion. This cost is just the cost for cleanup. Cleanup accounts for only two-thirds of the total costs of CERCLA. The other third of the costs involve enforcement (23:29). A 1992 study by Rand Corporation's Institute for Civil Justice showed that four national insurers spent as high as 88 percent of their Superfund related outlays on legal fees, coverage disputes and other non-cleanup items. On the other hand, large industrial firms spent only about 20 percent of their hazardous waste cleanup funds on these non-cleanup items (24:1). Using the estimate that cleanup is two-

Table II, Resource Requirements More Stringent Policy**

Remediation Authority	Plausible Lower Bound	Best Guess	Plausible Upper Bound
		($ Billions)	
National Priority List	246	352	704
RCRA Corrective Actions	188	258	423
Underground Storage Tanks	32	67	*
Department of Defense	*	70	*
Department of Energy	*	360	*
State/Private Programs	*	70	*
TOTAL	966	1,177	1,694

* The estimate is not thought to differ from the Best Guess
** Cleanup to allow future unrestricted use of site and groundwater

(19:22)

thirds of the total costs, the total cost to the nation would be over 1.765 trillion dollars.

A 1992 study conducted by EPA, to look at environmental pollution control costs, found that pollution control costs in constant dollars and as a percentage of GNP have been increasing over time since 1972. The study also found that they have been increasing at a decreasing rate and are expected to do so through 2000 (25:41). The annualized costs for RCRA and CERCLA listed in the report are shown in Table III. By 1995 the control of hazardous waste in the United States is expected to cost close to $17 billion a year and will reach almost $24 billion by the year 2000.

The Hazardous Waste Cleanup Project, a coalition of trade associations in the industrial sector, published a 1993 paper entitled "Sticker Shock: Recognizing the Full Cost of

Table III, Annualized Control Costs

	Annualized Control Costs (millions of dollars) 1987	1995	2000
RCRA Hazardous Waste	1,725	9,210	12,062
Underground Storage Tanks	1	2,920	3,691
Superfund	683	4,690	8,093
TOTAL	2,409	16,820	23,846

(25:38)

Superfund Cleanups". In the paper they state that between fiscal years 1980 and 1986, the majority of CERCLA cleanup work was funded out of the Superfund with PRPs paying only 30 percent of the remedial action. This has changed to over 80 percent of work, began in the third quarter of FY 1992, being funded by PRPs. This shift is important, the paper says, because direct private funding of cleanups gives the EPA less incentive to seek cost-effective cleanups, thus driving up the cost of cleanup. (26:3)

In addition to more of the funding for cleanups being born by the private companies, the size of the Superfund has grown as well. Initially funded at $1.6 billion the total cumulative funding has grown to $15.2 billion, almost ten times the initial funding (26:4).

Two major reasons account for this growth in spending. First, the number of sites has grown much larger than initially anticipated in 1980 and second, the cleanup costs per site are substantially higher than expected. In 1980, there were approximately 8,000 sites across the United States that were considered hazardous waste sites needing cleanup. By October of 1992, the number had grown to nearly 37,000.

Originally the EPA estimated the average cleanup cost would be $7 million per site. That estimate has grown to $25 million per site and some estimates place it at $40 to $50 million per site. Multiplying the average cost per site by the number of sites, we get a total cost for all sites. This total cost is $925 billion using an average site of $25 million or $1.850 trillion using an average site of $50 million. The reports say that other factors also contribute to the high cost of cleanups. These factors are first, cleanup levels at many sites go far beyond the levels necessary to protect human health and the environment; second, CERCLA makes cost a minor factor in selecting cleanup levels; and third, EPA has failed to adequately control contractors, resulting in allegedly tremendous waste. (26:4)

An article in World Wastes magazine in February 1994, states that the number of U.S. sites requiring cleanup could be as large as 75,000 (27:44). With someone needing to pay the tremendous cost to clean up these sites, the insurance industry is pushing for provisions to make the cleanup of hazardous waste sites a society responsibility instead of the liability of PRPs. Under the proposal, all societal partners in environmental pollution would pay a tax to fund the costs of cleanup. Other groups such as the chemical manufacturers, would prefer a fair-share approach, which would force those involved in pollution incidents to pay according to the amount of pollution for which they are responsible (27:44).

A 1993 study conducted by William T. Lorenz & Company found that total hazardous waste cleanup for 1993 in the United States was estimated at $14.46 billion. This is an increase of 40 percent since 1991 (28:12).

DOE estimates that their cleanup costs for FY 1991 through 1997 will be almost $41 billion. This is nearly $12 billion more than DOE expects to receive in funding (29:48). DOD's environmental budget for FY 1995-1999 comes to more than $50 billion (12:11). DOD's cleanup program is estimated to total $24.5 billion over the next twenty years. $5.7 billion of the $50 billion requirement was allocated for FY95. Of the $5.7 billion, $2.2 or almost 40 percent is slated for cleaning up hazardous waste sites. Of this amount, $800 million is to investigate and study suspected contaminated sites with the rest for actual cleanup (30:22).

Some feel that the military is not doing enough to clean up wastes. The Boston-based National Toxic Campaign Fund (1991) says:

> The failure to provide adequate funds is by far the greatest obstacle to the timely, proper cleanup of military hazardous wastes. (7:26)

In a 1994 letter to the Wall Street Journal, Admiral William A. Owens, Vice Chairman of the Joint Chiefs of Staff, and Sherri W. Goodman, Deputy Undersecretary of Defense Environmental Security stated that the military is currently spending under 2.5 percent of the defense budget on environmental efforts (31:A11).

The Air Force's environmental cleanup up requirements for FY 1995-1999 totals $5.2 billion. Of this amount only about 60 percent is expected to be funded (21:74). Major General James E. McCarthy, Civil Engineer of the Air Force, said "We are wire-brushing [the environmental budget] because every dollar we put in the environmental area takes away from some other vital Air Force program, including readiness" (21:75).

While the cost in different reports vary, the conclusion can be drawn from the literature that the cleanup of hazardous waste sites are a significant cost to the United States ranging from billions up to over a trillion dollars. The estimated costs of cleanups have risen over the years as more information about sites are known. This increase in costs is expected to continue into the future given the current trends. These costs are a significant cost to society and U.S. industry. The cost of cleanup of Federal facilities is a significant impact on U.S. taxpayers money.

Another conclusion common to a number of studies is that the high costs of hazardous waste can not just be assumed as being required but should be compared to the benefits generated. Expenditures and resource allocation decisions should be made based on getting the most benefits for the money expended.

The 1991 study conducted by the University of Tennessee's Waste Management Research and Education Institute appears to be widely accepted in the literature as a fairly accurate reflection of costs. It is cited and used as the estimate of

costs in several other studies. The Tennessee study also found DOD's own estimates to be a reasonable projection of costs and only modified them for cost growth and time required for O&M (19:A-3.39). Using this study as an accurate reflection would place the total cost of hazardous waste cleanup at $752 billion with DOD's portion accounting for $30 billion. The Air Force with 4,970 of the approximately 7,300 of the contaminated DOD sites will account for approximately $6.37 billion in costs. The funding for Air Force cleanups is already falling below that required. The Air Force is already scrutinizing the environmental budgets since they are now negatively impacting the funding of other vital readiness programs.

A 1994 report by the Congressional Budget Office said the cost of cleaning up DOD bases and facilities could top $45 billion (32:12). This is more than 50 percent greater than the DOD estimate and 50 percent greater than the University of Tennessee study estimate. The report also states that the rising costs of meeting acceptable environmental standards may slow the pace of base closings (32:12).

In summary, the costs of hazardous waste cleanups has become a major concern for the Air Force and the United States in general. Viable actions to help control and/or realign/reallocate cleanup costs are highly justified.

<u>B. RISKS OF HAZARDOUS WASTE SITES</u>

A discussion of the risks of hazardous waste sites needs to begin by looking at current procedures for conducting Risk

Assessments at hazardous waste sites. This Risk Assessment process is outlined in the EPA's Manual entitled "Risk Assessment Guidance for Superfund Volume 1 Human Health Evaluation". A baseline risk assessment as outlined in the guidance involves four separate steps. These steps are 1) Identification of Contaminants of Concern, 2) Exposure Assessment, 3) Toxicity Assessment, and 4) Risk Characterization.

1. Identification of Contaminants of Concern - The basis of the first step, identification of contaminants of concern, is data collection and evaluation. This involves gathering and analyzing relevant site data. This step identifies potential chemicals of concern to human health. Those substances identified as present at the site are then the focus of the rest of the Risk Assessment process.

Normally a site conceptual model would be developed to help guide the identification of all sources of contamination, their concentrations, and the media contaminated. An example of a generic conceptual model is shown in Figure 4. The types of data needed at the site for the risk assessment are:

- Contaminant identities
- Contaminant concentrations in the key sources and media of interest
- Characteristics of sources, especially information related to release potential
- Characteristics of the environment setting that may affect the fate, transport, and persistence of the contaminants

(5:4-1)

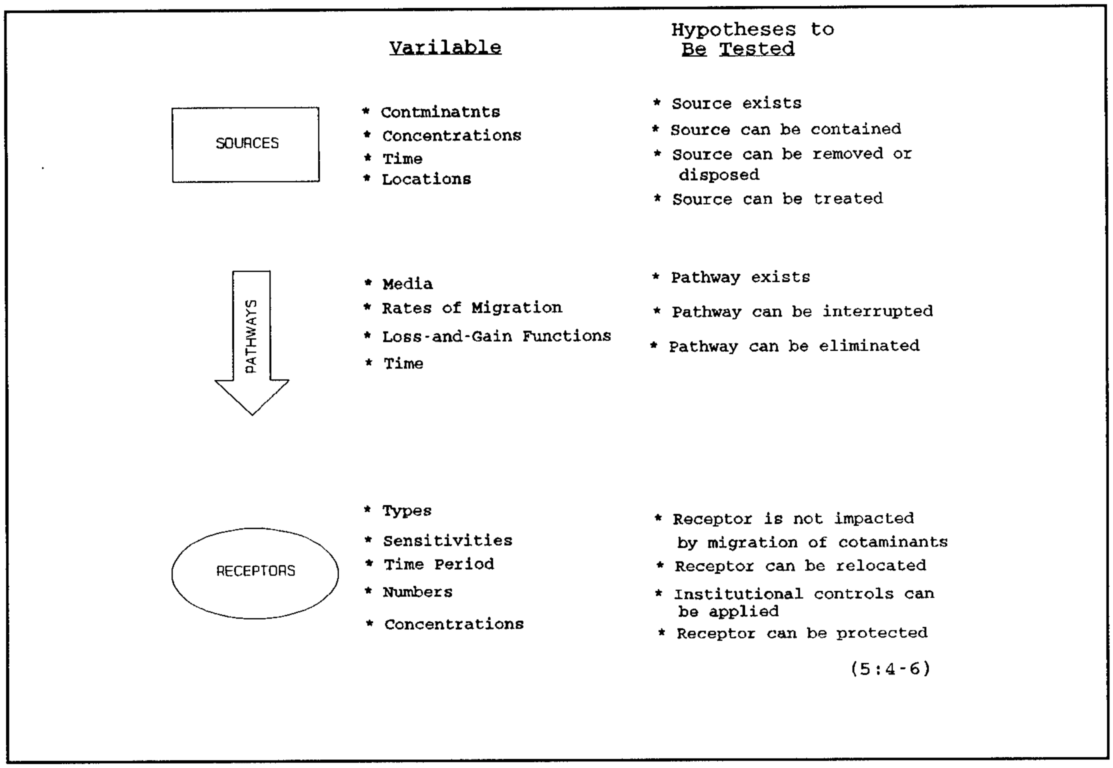


Figure 4, Conceptual Model

Normally when dealing with large and complex sites, extensive background sampling would be conducted. There are two different types of background levels for chemicals, the first, is naturally occurring levels. These are ambient concentrations naturally present in the environment that has not been influenced by humans. The second background level is an anthropogenic level, concentrations of chemicals that are present due to human activities, but which do not come from on-site activities. The nature of the surrounding areas can make on-site migration of off-site contamination a potential risk. Sampling of the groundwater as it flows onto the site

(as best as can be determined) should be accomplished. This would help give an indication of any anthropogenic background level.

Once the site sampling has been completed and the data has been collected, the data is organized in the form necessary for the risk assessment. The following steps should be taken to organize the data:

1) Gather all data available from the site investigation and sort by medium (air,soil, surface water, groundwater;

2) Evaluate the analytical methods used;

3) Evaluate the quality of data with respect to sample quantitation limits;

4) Evaluate the quality of data with respect to qualifiers and codes;

5) Evaluate the quality of data with respect to blanks;

6) Evaluate tentatively identified compounds;

7) Compare potential site-related contamination with background;

8) Develop a set of data for use in the Risk Assessment, and;

9) If appropriate, further limit the number of chemicals to be carried through the Risk Assessment (5:5-1)

The outcome of this organization and evaluation should be the identification of a set of chemicals or elements that are site-related and concentrations that are of acceptable quality for use in the quantitative risk assessment characterization (5:5-2).

2. Exposure Assessment - The second step in the risk assessment is the exposure assessment. The exposure

assessment involves three steps. These steps are shown in Figure 5. In characterizing the exposure setting the physical characteristics of the site to include climate, vegetation, ground-water hydrology, and presence and location of surface water are identified. The populations on and near the site are identified with respect to location relative to the site, activity patterns and sensitive subpopulations (5:6-2). This step considers the current population, as well as any future populations that may occur under a different future land use.

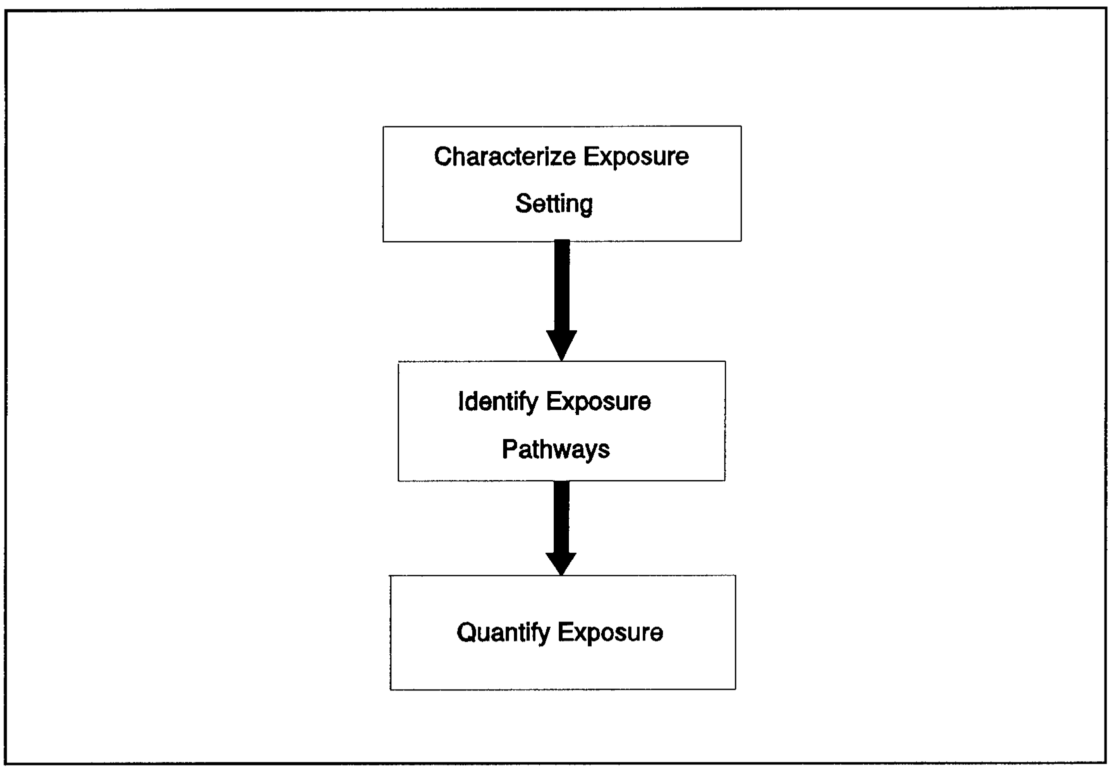


Figure 5, Exposure Assessment Steps

The pathways are then identified by which these populations may be exposed. Exposure points and routes of

exposure are identified for each exposure pathway. An example of a matrix of potential exposure routes is shown in Table IV.

Table IV, Exposure Routes

EXAMPLE OF MATRIX OF POTENTIAL EXPOSURE ROUTES

Recreational Population	Residential Population	Industrial Population	
<u>Groundwater</u>			
Ingestion	S	S	NL
Dermal Contact	S	S	NL
<u>Surface Water</u>			
Ingestion	NL	NL	NL
Dermal Contact	A	A	A
<u>Sediment</u>			
Incidental Ingestion	NL	NL	NL
Dermal Contact	NL	S	NL
<u>Air</u>			
Inhalation of Vapors			
Indoors	NL	NL	NL
Outdoors	NL	NL	NL
Inhalation of Particles			
Indoors	NL	NL	NL
Outdoors	NL	NL	NL
<u>Soil/Dust</u>			
Incidental Ingestion	C	A	A
Dermal Contact	C	A	A
<u>Food</u>			
Ingestion			
Fish	S	NL	S
Meat and Game	S	NL	NL
Vegetables	S	NL	NL

NL - Not Likely to be exposed
C - Exposure to Children
S - Slight
A - Average

(5:6-18)

In the quantification of exposure, the magnitude, frequency and duration for each exposure pathway is quantified. This is done by first determining the concentration of chemicals that will be contacted over the exposure period, then calculating the amount of intake or exposure to the chemical over the exposure period. Examples of the calculation of exposure to soil and groundwater are given in Tables V and VI respectively.

Table V, Soil Exposure Calculations

$$\text{Intake} = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

CS - Chemical Concentration in Soil (mg/kg)
IR - Ingestion Rate (mg soil/day)
CF - Conversion Factor (10^{-6} kg/mg)
FI - Fraction Ingested from Contaminated Source
EF - Exposure Frequency (days/year)
ED - Exposure Duration (years)
BW - Body Weight (kg)
AT - Averaging Time

(5:6-40)

The standard ingestion rate for groundwater and soil to be used in these calculations are given by the EPA and are shown in Table VII.

The decisions taken at the site based on the Risk Assessment are to use a Reasonable Maximum Exposure (RME). This Reasonable Maximum Exposure is the highest exposure that

Table VI, Groundwater Exposure Calculations

$$\text{Intake} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

CW - Chemical Concentration in Water (mg/liter)
IR - Ingestion Rate (liters/day)
EF - Exposure Frequency (days/year)
ED - Exposure Duration (years)
BW - Body Weight (kg)
AT - Averaging Time

(5:6-35)

is reasonably expected to occur at the site. This exposure can occur under either current or future land use conditions. The determination of the RME involves the use of professional judgement and is intended to provide a conservative exposure estimate.

Table VII, Standard Ingestion Rates for Humans

Ingestion of Groundwater		
	2 Liter/day	
Ingestion of Soil		
	200 mg/day	Age 1-6
	100 my/day	Older than 6

(5:6-35,6-40)

3. Toxicity Assessment - The purpose of the Toxicity Assessment is to provide an estimate of the relationship between exposure to the contaminant and the increased likelihood of adverse effects. The Toxicity Assessment is generally accomplished in two steps. The first step is Hazard

Identification. Hazard Identification determines whether exposure to a contaminant can cause an increase in the incidence of a particular adverse health effect and whether the adverse health effect is likely to occur in humans. The second step is Dose Response Evaluation. Dose response evaluation evaluates the toxicity information and develops relationships between the dose administered and the incidence of adverse health effects in the exposed population. This then can be used to estimate the potential for adverse effects as a function of exposure to the contaminant (5:7-1).

EPA has performed toxicity assessments for numerous chemicals. Normally the toxicity information for the contaminants of interest can be obtained through the Integrated Risk Information System (IRIS). This is EPA's toxicity assessment data base containing up-to-date health risks for numerous chemicals. Another source of toxicity information should only be used if the information necessary for the chemical being evaluated is not available in IRIS. To ensure up-to-date information, IRIS is only available in an on-line computerized form. The toxicity values are used in the risk characterization to determine the potential for adverse effects occurring in the exposed population.

4. Risk Characterization - The steps in the Risk Characterization process are shown in Figure 6. In the Risk Characterization, the Toxicity and Exposure Assessments are integrated into quantitative and qualitative expressions of risk. To characterize noncarcinogenic risks, comparisons are

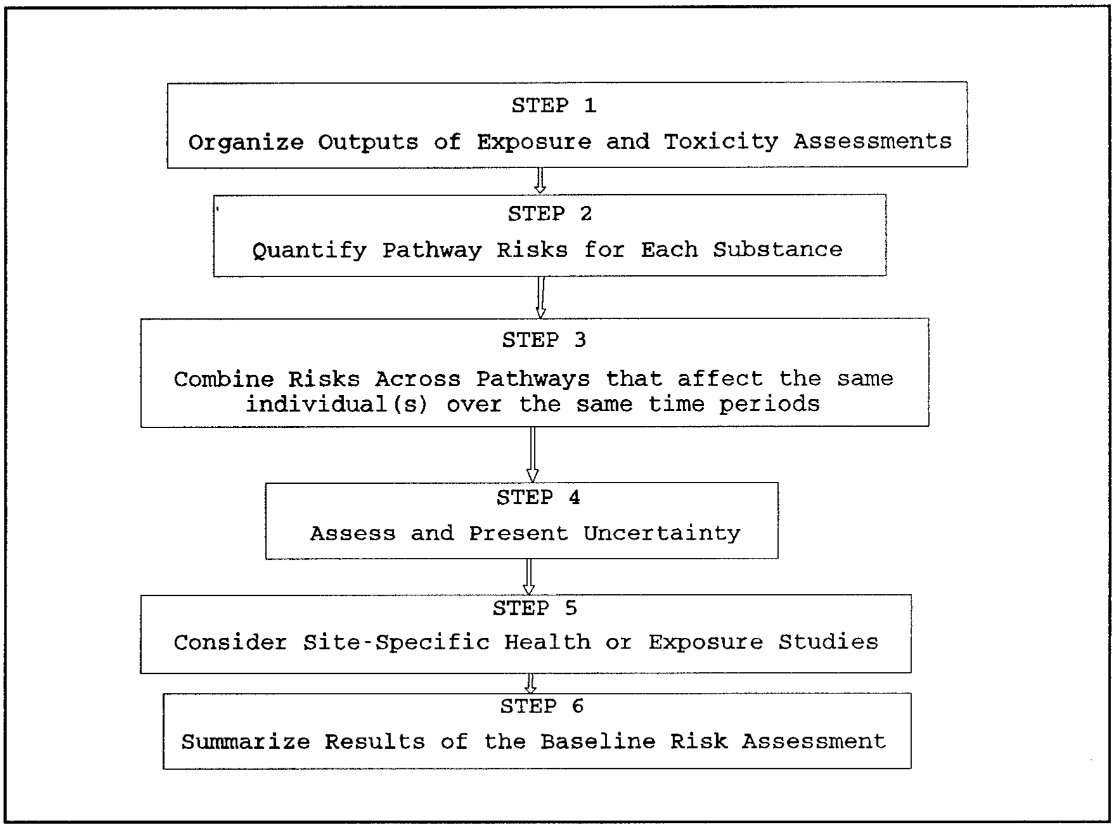


Figure 6, Risk Characterization Steps

made between the projected intakes of contaminants and their toxicity values. To characterize carcinogenic risks, probabilities that an individual will develop cancer over a lifetime of exposure are estimated based on projected intakes of contaminants and dose-response information.

The most common target risk levels used by the EPA for cleanup of Superfund sites is a 10^{-6} incremental risk (one in a million) for carcinogenic effects but a range of 10^{-4} to 10^{-6} is considered acceptable along with a Hazard Index (HI) of 1 for noncarcinogenic effects. A HI of 1 is the level of

exposure to a chemical which is unlikely for even sensitive populations to experience adverse health effects (33:15).

Richard Wilson in an article entitled "Analyzing the Risks of Life", presented a chart showing different activities that raise the chance of death by 10^{-6}, the factor used by the EPA in carcinogenic effects. This chart is shown in Table VIII. The chart takes a very serious matter, increasing the chances of death, and almost takes it to the point of poking fun. Something as serious as the public's health should never be taken lightly. The chart is not presented to lesson the importance of the subject, but to illustrate that 10^{-6} is a conservative figure and that it does not take much to increase risk by that amount.

The problem comes in when attempting to determine what cost should be spent at hazardous waste sites and what role doe the expenditures have in improving public health.

A 1993 paper written by George L. Van Houtven and Maureen L. Cropper, entitled "When is a Life Too Costly to Save", used a cost benefit approach in considering environmental standards and regulations. The paper stated that under the Toxic Substance Control Act (TSCA) and FIFRA, two statues that require the balancing of cost and benefits, the implicit value per cancer case avoided is in excess of $45 million in 1989 dollars. (35:18)

If this same figure applied to hazardous waste sites, the site would have to impact the health of 1 million people at the 10^{-6} level to justify a $45 million cleanup. Using the

Table VIII, 10^{-6} Chances of Death

RISK WHICH INCREASE CHANCE OF DEATH BY 10^{-6}

Smoking 1.4 cigarettes	Cancer, heart disease
Drinking 1/2 liter of wine	Cirrhosis of the liver
Spending 1 hour in a coal mine	Black lung disease
Spending 3 hours in a coal mine	Accident
Living 2 days in New York or Boston	Air pollution
Travelling 6 minutes by canoe	Accident
Travelling 10 miles by bicycle	Accident
Travelling 300 miles by car	Accident
Flying 1000 miles by jet	Accident
Flying 6000 miles by jet	Cancer caused by cosmic radiation
Living 2 months in Denver on vacation from N.Y.	Cancer caused by cosmic radiation
Living 2 months in average stone or brick building	Cancer caused by natural radiation
One chest x-ray taken in a good hospital	Cancer caused by radiation
Living 2 months with a cigarette smoker	Cancer, heart disease
Eating 40 tablespoons of peanut butter	Liver cancer caused by aflatoxin B
Drinking Miami drinking water for 1 year	Cancer caused by chloroform
Drinking 30 12 oz. cans of diet soda	Cancer caused by saccharin
Living 5 years at site boundary of a typical nuclear power plant in the open	Cancer caused by radiation
Drinking 1000 24 oz. soft drinks from recently banned plastic bottles	Cancer from acrylonitrile monomer
Living 20 years near PVC plant	Cancer caused by vinyl chloride
Living 150 years within 20 miles of a power plant (1976 standard)	Cancer caused by nuclear radiation
Eating 100 charcoal broiled steaks	Cancer from benzopyrene
Risk of accident by living within 5miles of a nuclear reactor for 50 years	Cancer caused by radiation

(34:14)

average site cost of $25 million, the site should impact 555,555 people's health by 10^{-6} to justify the expenditure under the same cost benefit ratio.

Dr. Richard Goodwin, a consulting environmental engineer who has overseen more than 20 toxic waste cleanups states:

> Does it make sense to spend millions of dollars cleaning up a site that only has a tenth of an ounce of contamination? I say no. All we're doing in most cases is throwing money at a problem without improving public health or the environment. (13:30)

If the money is not significantly improving public health, why is it being spent?

The EPA administrator in 1987, assigned a special task force to compare the risks associated with major environmental problems. The task force found that RCRA sites, underground storage tanks, and Superfund were considered relatively medium or low risk but were areas of high EPA effort. The EPA's priorities were found to more closely aligned with public opinion than with estimated risks (36:xv).

In 1990 the EPA's Science Advisory Board, concluded environmental laws are more reflective of public perceptions of risk than of a scientific understanding of the risk. William K. Reilly, the EPA Administrator at the time, recently stated:

> People have a right to expect that public officials are making the right choices for the right reasons. We need to develop a new system for taking action on the environment that isn't based on responding to the nightly news. We're misallocating large amounts of money. What we have had in the United States is environmental agenda-setting by episodic panic. We've had Love Canal, Valley of the Drums, the Exxon Valdez and with virtually every case of a new

> environmental crisis, there is a new legislative priority and a new budget allocation. That has created a mix of programs that don't respect the biggest risks to health and ecology. (13:30)

Senator Daniel Moynihan, chair of the Environment and Public Works Committee, wanted in 1992 to make risk assessment a permanent part of EPA's regulatory decision-making process. He believes doing this will make the agency's actions more coherent and less reactive to sudden public scares. The goal is for the agency to conduct decision-making in such a manner that decisions address the greatest risks to human health and the environment (37:51).

Frustration in the system was expressed by Governor Jim Florio of New Jersey when he said:

> It doesn't make any sense to clean up a railyard in downtown Newark so it can be a drinking water reservoir. (13:30)

There needs to be logic applied to the cleanup and the use of the land in the future.

A committee of the National Research Council in 1991 analyzed different studies in an attempt to investigate the possible link between hazardous waste sites and a variety of adverse human health effects. The conclusion was while exposures from hazardous-waste sites have produced serious health effects in some populations, a lack of good data makes it impossible to draw inferences about the overall nationwide health benefits provided by the Superfund program (23:13).

This problem with obtaining information from waste sites is explained in the 1987 book Health Effects from Hazardous Waste Sites:

> Health effects of waste site-related exposures may occasionally be acute and overwhelming such as those resulting from seepage of waste arsenic into a household well. More typically, however, exposures are less dramatic and any health effects that exist will most likely be subtle and difficult to detect. They will tend to be chronic and may remain asymptomatic and subclinical for long periods. (38:5)

This means the adverse effects of the sites may go undetected for long periods of time if discovered at all. The book further explains how these adverse effects are difficult to separate from those effects normally occurring in communities.

> Moreover, illnesses that do arise from chemical exposure can usually be expected to resemble or be identical with "background" health problems in a community such as nerve damage, cancer, or miscarriage. Also, since many communities surrounding waste sites are small and hard to define, statistical reliability may be inherently impossible to attain. (38:5)

This lack of information creates uncertainty. David D. Doninger, a senior lawyer with the National Resources Defense Council stated (1993) the views of many when dealing with uncertainty when he stated:

> For 35 years, the policy of the Government has been that when there is uncertainty about a threat it is better to be safe than sorry. When you are operating at the limits of what science knows, the big mistake would be to underestimate the real danger and leave people unprotected. (13:30)

Forty percent of the U.S. population relies on groundwater as a source of drinking water. This makes contamination of drinking water the largest waste site related health problem.

The shear numbers make the scope of the health problem significant. (38:4) Groundwater contamination is the most serious problem at the majority of Superfund sites. The nature of groundwater flow complicates the contamination issue. Toxic chemicals in groundwater are not stationary, but move in a plume of contamination. The direction and rate of movement of the contamination plume in groundwater is often unpredictable without a thorough and costly hydrogeological investigation. Even a thorough investigation may produce inaccurate predictions of contamination movement. Contaminated groundwater is extremely difficult and expensive to cleanup. (39:473) When dealing with the uncertainty that is inherent in groundwater, isn't it best to be conservative when attempting to protect the public's health?

The majority of the Air Force's 4,970 contaminated sites are contaminated with fuel, solvents, oil and other liquid wastes that leaked into the ground from spills, underground storage tanks, and fire training pits. These three sources account for 54 percent of the Air Force's hazardous waste sites. (21:76)

A study on the effects of groundwater contamination on property values had interesting results. Commercial and industrial property markets quickly adjusted to include the cost of groundwater contamination in the value of the property. However, residential property values were unaffected by groundwater contamination. (39:479) Is it

because as a nation we assume that the government will always assure we have a safe form of drinking water in our homes?

To determine the actual risk to the public posed by the various chemicals at hazardous waste sites requires a toxicity assessment. The toxicity assessments that are used in the risk assessment process are usually derived from animal studies. The government's most important diagnostic tool in identifying environmental problems that pose a threat to human health has been rodent studies. Dr Kenneth Olden director of the National Institute of Environmental Health Sciences, the branch of the National Institutes of Health that directs animal studies said:

> The findings from about 450 animal studies over the last several decades have led Federal and state governments to write thousands of regulations forcing government and industry to spend tens of billions of dollars a year regulating the use and disposal of several dozen chemicals, or finding alternatives for chemicals that have been restricted or banned. That's an awful lot of money to be spending to be regulating substances we might not have to be regulating at all if we had more information. (40:1)

Dr. Olden makes this statement among increasing skepticism about the rationale being used in rodent studies. In the studies the rodents are fed the "maximum tolerated dose (M.T.D.)". This is the maximum dose the animal can tolerate without death from poisoning. In 1991, Dr. Olden asked a group of experts to study his agency's toxicology research. The group reported that the maximum tolerated dose approach does not appear to be valid. The group wrote:

> Approximately two-thirds of the carcinogens would not be positive, i.e., not considered as carcinogens, if the M.T.D. was not used. (40:1)

If all the information is not known, is it best to spend millions on dollars protecting the public from unsubstantiated risks or not spend the money and have the actual risk substantiated later in time.

One of the major exposure routes used in the risk assessment process is the assumption that the soil at sites will be eaten. The goal usually is to clean the soil to a level that children can eat the soil without risk. The EPA has acknowledged that half of the money spent on Superfund cleanups are to comply with the levels necessary for these "dirt-eating" assumptions (13:30). These dirt-eating assumptions are coming under criticism. The assumption values the EPA uses for dirt ingestion were shown earlier in Table VII. The EPA figure for adults is that 100 mg of soil per day is assumed to be ingested. Studies by Edward J. Calabrese and others have found that 50 mg/day is a closer approximation than the 100 mg used by the EPA (41:94). This one factor would double the exposure calculated in the risk assessment, thus doubling the potential risk. Calabrese in studying the soil ingested by young children used tracer elements to try and estimate the quantity of soil ingested. The eight tracers used gave estimates ranging from 9 to 96 mg per day. The three tracer elements viewed as most reliable gave values ranging from 9 to 40 mg/day (42:123). Even using the highest value in the range is considerably less than the

200 mg/day estimate that is used by the EPA in the exposure assessments.

Table IX, Example: Exposure Assessment

Example: Exposure Assessment

	Reasonable Single Point Estimate	EPA Method	Overestimation
Chemical Concentration in soil	40 mg/kg	361 mg/kg	9.03 times
Rate of soil ingestion	25 mg/day	100 mg/day	4.00 times
Frequency of exposure	35 day/yr	350 days/yr	10 times
Duration of exposure	9 years	30 years	3.33 times
Calculated exposure	.0000018mg/kg/day	.00021mg/kg/day	1,167 times

(43:16)

The Hazardous Waste Cleanup Project, a coalition of trade associations, in a report entitled "Exaggerating Risks: How EPA's Risk Assessments Distort the Facts at Superfund Sites Throughout the United States", used an example to demonstrate the effect of EPA's conservative estimates on exposure assessments. They compared EPA's conservative estimates to what they viewed as a more reasonable estimate. This comparison is shown in Table IX. While the values used by the Hazardous Waste Cleanup Project as a "more reasonable estimate" appears to be on the low end of any acceptable values, the table does demonstrate the potential cumulative effect of using the most conservative value as called for in the EPA method.

There has been documented health effects from specific hazardous waste sites in areas such as Love Canal, New York; Hardeman County, Tennessee; San Jose, California; and Woburn, Massachusetts (3:23). However, sufficient information to determine the benefits generated from the vast expenditures on hazardous waste cleanups in not available. What is known is that 40 percent of the U.S. population relies on groundwater as a source of drinking water. This makes the potential risk to the public from hazardous waste sites significant. The public must be protected for the potential risk from these sites.

The risk to the public is determined by a risk assessment. The EPA uses a specific step by step process to determine the risk assessment at a hazardous waste site. This process uses conservative assumptions in an attempt to characterize the risk to the public. The goal is to protect the public from undue risk to human health.

This conservative approach is now coming under attack for a variety of areas. Some feel the method is too conservative and inflates the actual risks. Others feel that animal studies upon which many risks are based are unreliable. Others feel the EPA is placing emphasis on hazardous waste sites based on public perceptions and not on actual risks. The general consensus appears to be that the levels and goals used by the EPA are viewed as conservative and therefore will adequately protect public health.

C. COST REDUCTION METHODS

A critical study of Superfund conducted by the Congressional Office of Technology Assessment concluded that between 50 and 70 percent of spending by the government and industry on Superfund is inefficient. One of the major reasons cited is that about 50 percent of cleanups address speculative future risks (3:3). The study examined several hundred cleanup decisions over several years and concluded that as many as 50 percent of cleanup decisions addressed future, uncertain risks. This was confirmed with a study by Oak Ridge National Laboratory that found two-thirds of groundwater cleanups and one-third of soil cleanups were for sites without current risk. (3:12)

If one assumes that only sites with a current risk should be cleaned up at this time, then 50 percent of the expenditures are misspent or a 50 percent savings is possible. This approach however, ignores any potential future risks posed by sites. Few people would argue that cleaning up chemically contaminated land and water for us and future generations is wrong. The real question is: How much cleanup is really necessary? The OTA report states:

> Insisting on perfect, quick and certain solutions, and ignoring resource limits can defeat cleanups of specific sites and threaten the national program. Conversely, insisting on low-cost cleanups can compromise protection of health and environment. (3:26)

The study further recommends replacing the current list of nine criteria for selecting a remedy with two steps. These steps are: 1) analyze each alternative for its ability to meet

cleanup objectives (action levels), and 2) estimate the full cost of each cleanup alternative. This will allow the selection of the lowest cost alternative that can meet the cleanup objectives. While the report does not quantify the amount of savings this approach would generate, it does imply that savings would be possible while still protecting the public's health. (3:66)

An article by William A. Duvel Jr. on ways to control cleanup costs listed the following ten management guidelines:

- Focus on the factors with the greatest influence on costs
- Use the power of fate/transport and risk assessment
- Collect enough information
- Collect the right information
- Focus on the results
- Control the process
- Control the contractors
- Pay attention to the work
- Move with Purpose
- Find other parties to share the costs (44:235)

Under the first factor, Duvel explains that the largest costs in the hazardous waste process are the actual remediation and operation of the site, accounting for 71 percent of the costs. The actual remediation costs stem from two factors; the quantity of material that requires remediation and the unit cost of remediation. These two factors have the greatest impact on the cost of hazardous waste remediation. The

quantity of material is a function of the cleanup levels or action levels. These levels are derived from the risk assessment. The unit cost of remediation is a function of the quantity of material (quantity discount) and the cleanup technology used. While the unit cost of remediation goes down as the quantity goes up the total cost increases. From a total cost reduction aspect the cleanup technology is the single most important factor for reducing the unit cost. Duvel is suggesting that to save money on remediation then cost saving measures should be applied to those aspects for which the costs are greatest. Placing emphasis on these factors will generate the most cost savings. For hazardous waste sites these factors are the Action Levels determined from the Risk Assessment and the cleanup technology selected from the Feasibility Study.

In the second guideline, Duvel says that because risk assessment has such an impact on the cost of the cleanup, it must be site-specific and deal only with risks posed by that particular site. Standard cleanup levels may be too conservative for a specific site and drive up cleanup costs needlessly. (44:236)

In the fifth guideline he emphasizes that the results of remediation is to have a clean site at the lowest cost. Focusing on the end results throughout the process will ensure a more cost-effective solution (44:242).

The current CERCLA legislation expired on 1 October 1994. Changes to this legislation will have an impact on the costs

associated with site cleanups. The Clinton administration's proposals of reforms to the legislation was sent to Congress the first part of February 1994. The reforms were aimed to make the Superfund cleanups faster, fairer and more efficient (45:7). EPA administrator Carol Browner states (1994) that one of her goals is to make it easier for cleaned-up properties to be redeveloped in ways that put sites back into productive use (45:7). The administration's proposals are modeled after the 1993 recommendations of the National Commission on Superfund comprised of both business and environmental representatives. The proposal calls for national generic cleanup levels for common toxics. This is hoped to standardize cleanups and eliminate the need for extensive study. This also would eliminate the requirement to comply with ARARs (46:36). It does however, also allow for some use of site-specific risk factors. The standards would factor in several variables such as future land use of the site. The community would have a voice in deciding future land use expectations to be used in the remedy selection process (47:6-7). The proposal also allows for alternative strategies to replace the current preference for permanent treatment at every site (47:6-7). The proposal is expected to cut the cost of cleanup by 20 percent by taking future land use into consideration, conducting risk assessments on realistic assumptions, and eliminating the ARAR requirement (45:44). The proposal has much of the business communities support along with environmental groups such as the Sierra

Club. In June 1994 the proposal cleared a Senate subcommittee on a 6-4 partisan vote (48:B4).

The management of public perceptions of hazardous waste sites can also effect the eventual costs. Failing to properly manage the public perceptions at cleanup sites can increase the costs by causing unnecessary delays, additional studies, and overly strict remedy (49:321). The management of public perception is generally a cost preventative measure. It is a proven method to keep costs from increasing needlessly rather than a way to reduce the costs.

The management of environmental programs has also reduced costs for some companies. While good environmental management programs are expensive and time consuming, a simple cost-benefit analysis will provide overwhelming evidence in support of a strong program. A good management program can save considerable money for a company in the long-term (50:16). While it saves money, this like public perception, is generally a cost preventive measure.

In the 1991 study of resource requirements to cleanup hazardous waste sites in the United States conducted by the University of Tennessee, they estimated not only the cost under the current policy but also under a more stringent policy and a less stringent policy. The more stringent policy has been presented earlier with the costs shown in Table II. The less stringent policy is a policy depending less on destruction and more on the containment or isolation of the

waste to minimize the likelihood of exposure (19:12). The result of this policy is shown in Table X. The potential

Table X, Resource Requirement Less Stringent Policy**

Remediation Authority	Plausible Lower Bound	Best Guess	Plausible Upper Bound
		($ Billions)	
National Priority List	63	90	180
RCRA Corrective Actions	150	199	316
Underground Storage Tanks	32	67	*
Department of Defense	*	18	*
Department of Energy	*	92	*
State/Private Programs	*	18	*
TOTAL	373	484	691

* The estimate is not thought to differ from the Best Guess
** Depends less on destruction and more on containment to isolate and minimize exposure

(19:22)

savings between the current policy and the less stringent policy, according to the study, is almost 36 percent for the nation as a whole or 40 percent for the Department of Defense. This represents significant potential savings.

Different studies and agencies have proposed or recommended different ways of reducing costs at hazardous waste sites. Just a few are shown and briefly explained in Table XI. These proposals are based on the need to control the costs of hazardous waste sites while at the same time protecting the public from undue risk and exposure.

Table XI, Summary of Potential Cost Savings Measures

Summary of Potential Cost Savings Proposals

University of Tennessee Study	40%
Administration's Superfund Proposals	20%
OTA Study	50%
House Appropriations Committee	26%

University of Tennessee - based on using a less stringent policy depending less on destruction in favor or isolating the contamination to minimize the likelihood of exposure (19:12).
OTA - based on the findings that 50 percent of cleanups are for sites without current risks (3:3). This savings assumes that money is spent only to address current risks and not future risks.
Administration's Proposal - estimate based on taking future land use into consideration, conducting risk assessments on realistic assumptions, and eliminating the ARAR requirement (45:44).
House Appropriations Committee - this is based on a 26% reduction to cleanup appropriations by the committee based on considering future land use (20:1).

No one would argue that the public health must be protected or that contaminated hazardous waste sites should be cleaned up. The problem is at what cost to society should this work be done. If a site can be cleaned to a level that protects the public health for $10 million but some contamination remains, is this acceptable? Or should $20 million dollars be spent to remove all contamination from the site. This hypothetical question is played out for real at sites throughout the country. It is easy for the public to say that the site must be cleaned of all contamination if they are not directly bearing the costs. But with Federal sites all taxpayers bear the burden of the cost of cleaning the sites. Is this additional cost justifiable to the average taxpayer?

For the Literature Review it is clear that the cost of Hazardous Waste Sites is a significant cost to the nation.

Any method that will reduce these costs while protecting the public's health is justified. The actual savings possible from land-use restrictions has not been quantified. This study is necessary to determine the actual savings that is possible to the public and the Air Force at Hazardous Waste Sites at Air Force Closure Installations.

III. RESEARCH METHODOLOGY

Various reports and studies conclude that significant differences in savings are possible in completing hazardous waste remediation. Any unachieved potential cost savings is a serious matter to Commanders of "Major Commands" because all dollars now authorized by the Congress must be spent from one consolidated fund. Overruns in waste remediation mean less funds available for equipment maintenance and force training. Less-than optimal base closure remediation therefore reduces military readiness. A few typical cost savings proposals were discussed in the Literature Review and were shown in Table XI. This research quantifies the potential cost savings to remediation of Air Force closure sites by the use of land-use restrictions as outlined in Section I of this dissertation. In addition, this research analyzes the subjective opinion of individual Air Force environmental managers responsible for Air Force IRP sites, as relates to potential remediation cost savings measures.

This section describes the methodology to be used in the research project.

A. RECORDS OF DECISION

The heart of this research effort is analysis of the Records of Decision (RODs) for Air Force closure installations. These RODS are the official documentation of the selection of the remediation method for uncontrolled hazardous waste sites specified by CERCLA and oversighted by the Environmental Protection Agency. These RODs become public

documents and are available for purchase through the National Technical Information Service (NTIS), Springfield, Virginia. For access to closure-base RODs, addresses of the environmental point-of-contact personnel for each of the 26 Air Force closure bases was obtained from the Air Force Center for Environmental Excellence. Letters were sent to all of the bases requesting environmental cleanup RODs. Not all RODs have been completed or were available. Those bases that have reached the ROD stage on one or more cleanup site are shown in Table XII. Completed RODs tend to represent remediation

Table XII, ROD Status of Closure Installations

Reached ROD Stage	Have Not Yet Reached ROD Stage
Bergstrom AFB	Chanute AFB
Castle AFB	Carswell AFB
George AFB	Eaker AFB
Loring AFB	England AFB
Mather AFB	Gentile AFB
Norton AFB	Griffiss AFB
Pease AFB	Grissom AFB
Plattsburgh AFB	Homestead AFB
Williams AFB	K.I. Sawyer AFB
	Lowry AFB
	MacDill AFB
	March AFB
	Myrtle Beach AFB
	Newark AFB
	Richard-Gebaur ARB
	Rickenbacker ANGB
	Wurtsmith AFB

programs initiated before the formal, congressionally-mandated closure process and for those prioritized bases and installations identified to pose the greatest threat to public

health and the environment. Because of the relatively small sample size of closure-base RODs alone, the sample was expanded to include several RODs from bases that were not on the closure list. The following information was sought and analyzed in the RODs

- Land-use scenarios used in the Risk Assessment for the site;
- Risks to human health from current land use;
- Future land use considered in the Risk Assessment, and;
- Risks to human health associated with the future land use

The analysis follows the following process. Each ROD's selected remedy cost will be determined. Current and future site risks are then obtained from the Risk Assessment, as reported in the ROD. The acceptable level of risk will be identified from State policy. Comparison of current site risk is then determined as to minimal acceptable level of risk. If current risk exceeds the acceptable level, then some cleanup at the site would be necessary even if land-use restriction was implemented. For purpose of this dissertation it is then assumed that this site is not a candidate for savings from land-use restriction. It is possible that land-use restriction could reduce the amount of contaminated media requiring cleanup, but these quantities are not given in the ROD, thus making it impossible to quantify this savings from the information given. The assumption that no savings are possible therefore results in a conservative estimate.

If the current risk is less than the acceptable level, then the future risk will be compared to the acceptable level of risk. If the future risk is less than the acceptable level, the site is a candidate for the No Action alternative. Most No Action alternatives still have costs associated with future monitoring. If the future risk is greater than the acceptable level, the land-use of the future risk will be examined. If the land-use is different than current land-use, then the site is considered as a candidate for land-use restriction. A determination will be made as to whether land-use restriction would reduce the risk to an acceptable level. If not then the site will no longer be considered a candidate for savings from land-use restriction. This may not be totally true. It is possible that land-use restriction could lower the risk, not within an acceptable range, but to a level reducing the quantity of contaminated media requiring cleanup. Once again however, the quantities of contaminated media are not contained in the ROD to allow for quantification of this possible savings. This provides further conservatism to the calculated savings.

If land-use restriction would prevent unacceptable future risk, then the costs associated with the implementation of a land-use restriction alternative will be determined. This cost will then be subtracted from the selected remedy cost to determine the possible savings from land-use restriction. A graphical representation of this analysis process is given in Figure 7.

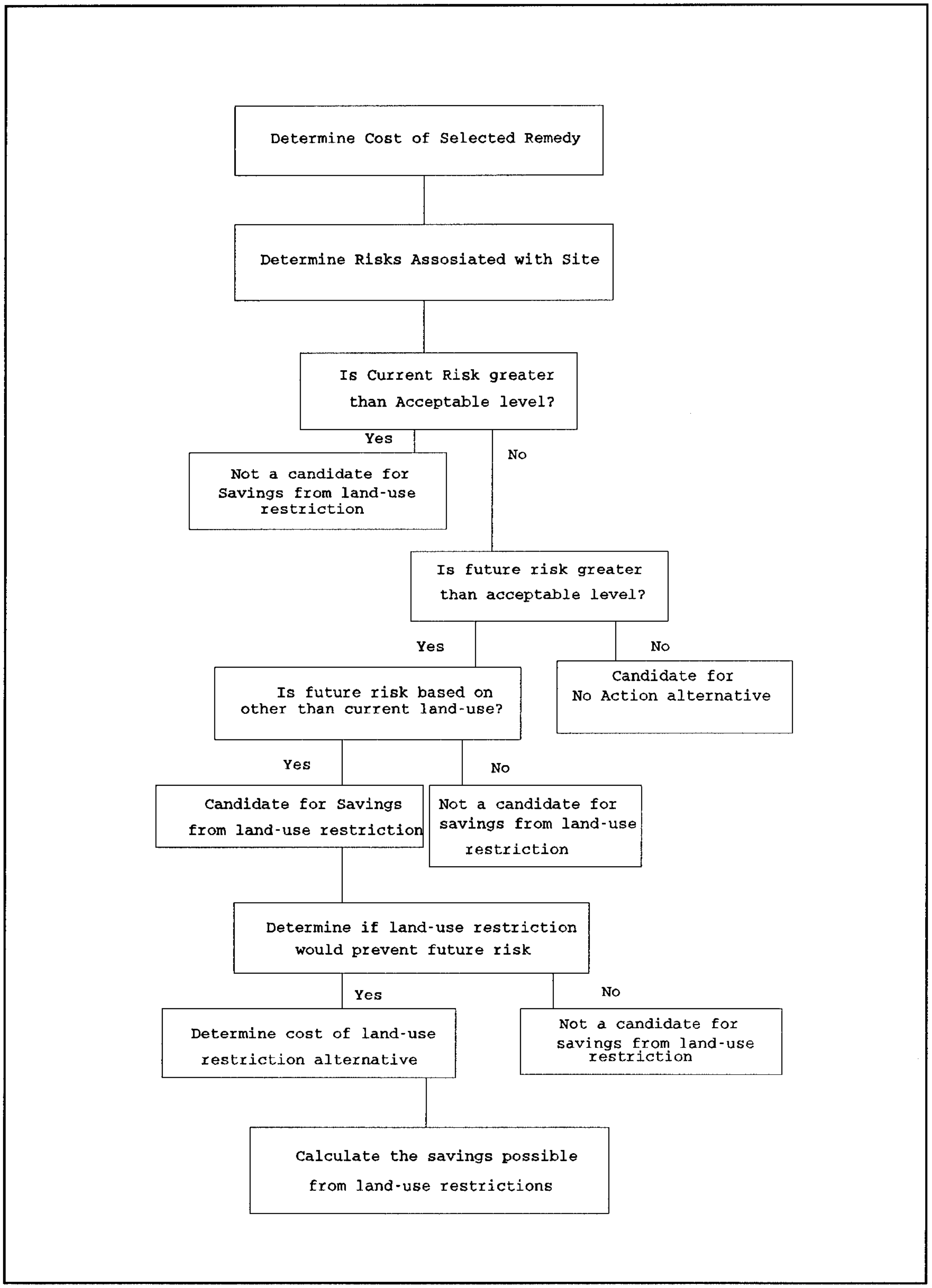


Figure 7, ROD Analysis Process

The primary source for all cost figures is taken to be the ROD itself. The cost of the land-use restriction alternative will be extracted from the ROD as much as possible. If sufficient information is not given in the ROD, then an appropriate cost estimate will be generated using the Environmental Estimating (ENVEST) portion of the Remedial Action Cost Engineering and Requirements (RACER) program adopted in 1993 by the Air Force (51:1-1). All costs will be expressed in Present Worth.

B. COST ESTIMATING (Remdial Action Cost Engineering and Requirement Program)

This computer program was developed as a result of the Air Force determination that it needed the capability to estimate the potential total costs of individual phases of environmental remediation. After surveying available cost estimating tools, the Air Force decided that there was no sufficiently comprehensive tool available which would effectively estimate and total costs of all phases of remediation. RACER uses a selection of pre-formulated parametric models of cleanup systems to estimate the cost of remediation. The actual unit prices come from the U.S. Army Corps of Engineers Unit Prices Book (51). ENVEST was developed in 1992 for the Air Force by Delta Research Corporation, of Niceville, Florida. The purpose of the ENVEST system is to enable the user to effectively estimate and manage costs during the investigation, remediation, and close out stages of the DOD Base Installation Restoration Program.

The calculated potential savings to remediation from implementation of land-use restriction will be compared to the subjective opinion of environmental managers, that work closely with IRP sites, on the amount of savings they feel is possible through land-use restriction. Major departures between calculated and subjective values do not invalidate either figure. Rather, such differences sense to flag and stimulate questions concerning already established estimates and therefore constitute a progammatic management methodology that can be applied at any level of review from the Department of the Air Force to Congress. The subjective opinion was obtained by means of a survey as discussed in the following section.

C. SURVEY INSTRUMENT (Questionaire)

A survey was administered to Air Force base-level environmental managers. The survey process that was followed is shown in Figure 8. The purpose of the survey was to elicit a subjective opinion of potential cost savings that could result from land-use restrictions and other potential cost savings measures that could be implemented at IRP sites. The author's survey instrument (questionaire) required pre-approval from the Air Force Institute of Technology (AFIT) Wright-Patterson AFB, Ohio and Air Force Military Personnel Center, Randolph AFB, Texas. The survey was reviewed and returned without comment on 7 November 1994 with the assignment of Air Force Survey Control Number 94-90.

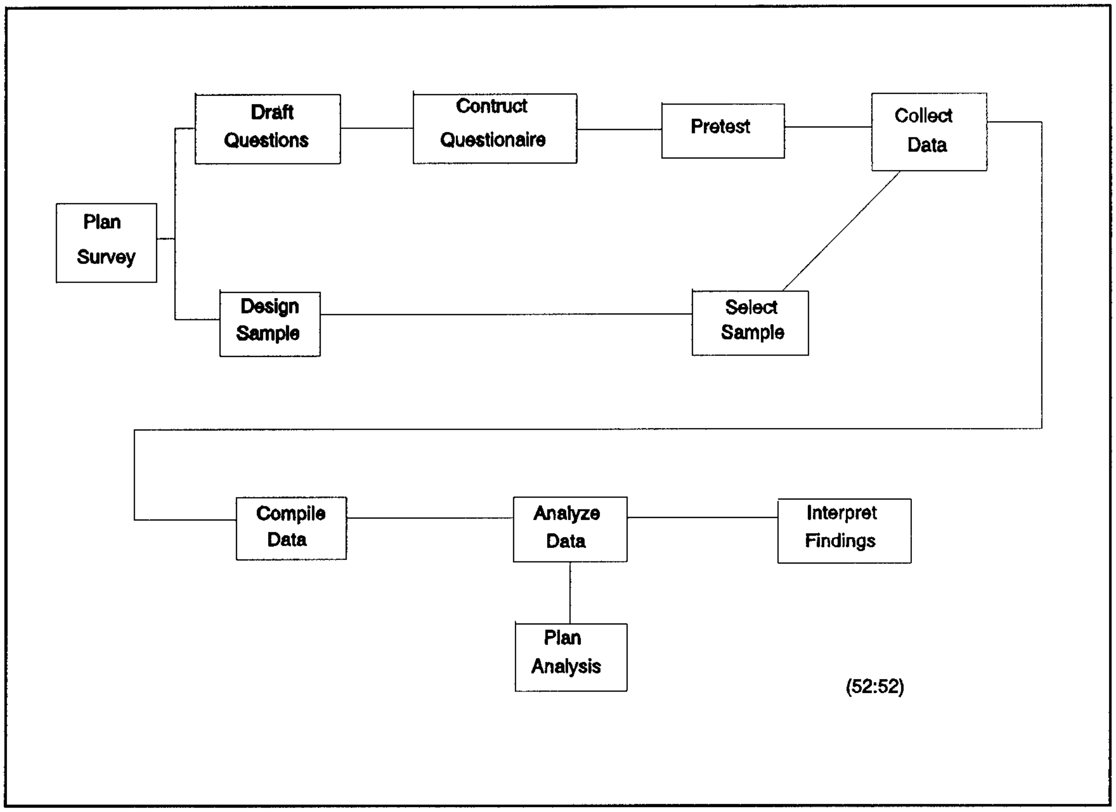


Figure 8, Dissertation Survey Process

A pretest of the questionnaire was conducted by the author, at five of the Air Force closure bases. All five pretests were returned. After review of the pretest comments and results the final survey was sent to the base-level Civil Engineering Squadron Environmental Officer at 60 Air Force bases (Appendix B) and the 21 closure bases not included in the pretest. The address of the Base Environmental Offices were obtained from each Major Command's Office of Environmental Programs.

The survey consists of 12 questions and was to be completed by one individual per base. A copy of the survey instrument appears in Appendix C. A letter of explanation was

sent with the survey requesting the survey be completed by the individual in the organization that is most familiar with and who has worked the longest with the base IRP sites. Postcard follow-ups were conducted after the survey was sent to increase the survey return rate. Completion of the survey by the recipients was not mandatory since the survey is not considered to be official Air Force business.

The data received from the survey were analyzed using the computer program, Statistical Package for the Personal Computer (SPPC; Walmyr Publishing Company, Tempe Arizona). The survey choices of potential cost savings measures were:

- Land-use restrictions
- Increased use of containment
- Standardized cleanup levels
- Realistic risk assessments
- Emerging innovative technologies

These methods were rank-ordered by the author, based on the survey data results. Statistical tests were applied to the data summaries to determine if the following factors had a significant impact on individal responses to the Cost Savings Measures.

- Number of years experience with IRP
- Number of IRP sites at the base
- How far in the CERCLA process the sites had progressed
- Air Force Major Command

The correlation was tested using the Chi-square statistical test, a frequently-used means of establishing relative significance. Chi-square is used as a statistical analysis procedure for survey data when the responses are given in discrete ranges and the values are not continuous. It is based on the null hypothesis: the assumption that there is no

relationship between the two variables in the total population. Chi-square is computed as shown below.

(Observed-Expected)^2/Expected

1) Subtract the expected frequency of occurance from the observed frequency
2) Square this quantity
3) Divide the squared difference by the expected frequency.

Chi-square values provide an indication of the overall discrepancy between the observed conjoint distribution in the sample and the distribution that we should have expected (based on empirical experience) if the two variables were actually unrelated to one another. (53:310) Chi-square provides a basis for rejection of a hypothesis of independence-between-variables (54:231).

The computed value of Chi-square is compared to a distribution of values that represent the number of times the value would expect to exceed the value if there was independence-between the variables. This can be expressed as a probability (p). If this value is low such as .05, this means the calculated value of Chi-square is exceeded by a Chi-square value for two independent variables in only 5% of occurances. Another way of stating this is that you have a

95% confidence that there is a relationship between the two variables. (55:153)

D. CERCLA AND IRP ANALYSIS

In order for the Air Force to be able to realize the potential savings of implementing land-use restrictions options it must be legal and possible to implement these restrictions. To determine if certain land-use restrictions are possible under CERCLA and DOD IRP regulations and guidelines, one must first understand the difference between *laws*, *regulations* and *guidelines*. The United States Congress is responsible for establishing the need for legal action to compel environmental action and enacting requisite laws, then reviewing their performance, then modifying on the basis of experiences. Once a law is passed by Congress, it goes to the executive branch agency responsible for implementing that Title of the Federal law. In the case of environmental law, that is the Environmental Protection Agency (EPA). The appropriate executive branch agency then creates Federal regulations that implement the intent of the congressional law. These requirements are published in the Code of Federal Regulation (CFR), and apply to all individuals and organizations for whom the law was intended to regulate. All government agencies can also write internal regulations directives, and guidelines for 1) control of their own employees, and 2) to provide *directives* and *guidance* for meeting Federal regulations.

CERCLA is a Federal law enacted in 1980. Its major provisions were implemented in December 1982 with the promulgation of the first National Oil and Hazardous Substances Pollution Contingency Plan (NCP). NCP was modified from an earlier document created in 1968 by the U.S. Coast Guard. In January 1987, certain specific CERCLA responsibilities were delegated by the President to executive departments and agencies by Executive Order 12580. In 1984, the Defense Appropriation Act passed by Congress established the Defense Environmental Restoration Account (DERA), to fund IRP for DOD installations within the Continental United States (CONUS). In 1986, Superfund Amendments and Reauthorization Act (SARA) was passed by Congress as the revised CERCLA of that year. SARA established the Defense Environmental Restoration Program (DERP) and added Section 120 to CERCLA relating to Federal facilities. (8:2)

Potential land-use restrictions at closure bases must be judged for compliance with CERCLA and SARA as a requirement for implementation. These Federal laws can only be changed or modified by Congress. CERCLA and its reauthorization, SARA expired without Congressional action on 1 October 1994 and are currently under review for reauthorization. The reauthorization proposal, H.R. 4916, was obtained by the author from the office of Representative John D. Dingell, Chairman of the House of Representatives Energy and Commerce Committee, and was reviewed herein for selection of compliance requirements.

The actual reauthorization that will be passed by Congress will probably differ slightly from the current proposal. However, review of the current proposal will give a rough indication of the potential for compatibility of land-use restriction in the final bill.

If candidate land-use restrictions at closure bases are in violation of Federal regulations, they can not be implemented in that specific format. Regulations can be modified by the Environmental Protection Agency, after public comment, if such changes are within the intent of the law.

If a proposed land-use restriction is judged to violate an internal regulation or guideline of a Federal agency, it can still be implemented through a waiver authorized by the approval authority and the Regional Administrator of EPA.

The implementation analysis of this dissertation reviews CERCLA and SARA as contained in a compilation of environmental laws published by the Government Printing Office for the House of Representatives Energy and Commerce Committee (56). The reauthorization proposal H.R. 4916 is also reviewed for compatibility with land-use restriction.

E. PROCEDURAL ANALYSIS

Even if the use of land-use restriction is possible within the constraints of CERCLA and SARA, the CERCLA process and procedure as outlined within EPA regulations, must be capable of procedural modification to allow land-use restrictions to be considered as a viable option prior to the

selection of the final remediation method. The current CERCLA process was evaluated to determine the best method for land-use to be considered within current guidelines without major process changes or modification.

IV. FINDINGS AND RESULTS

A. ROD ANALYSIS AND COST ESTIMATES

A total of 16 environmental cleanup RODs were obtained from 12 different bases. In addition the ROD for the Disposal and Reuse of Bergstrom AFB was obtained. A listing of the RODs is given as Table XIII.

Table XIII, ROD Listing

ROD Listing

1. Bergstrom AFB, TX, Disposal & Reuse *
2. Castle AFB, CA, Interim OU1 *
3. Castle AFB, CA, OU2 *
4. George AFB, CA, OU1 *
5. Hill AFB, UT, OU4
6. Loring AFB, ME, OU2 *
7. Loring AFB, ME, OU7 *
8. Mather AFB, CA, Aircraft Control&Warning Site*
9. McClellan AFB, CA, Interim OUB1
10. Norton AFB, CA, Central Base Area *
11. Pease AFB, NH, Site 8 *
12. Pease AFB, NH, Zone 5 *
13. Plattsburgh AFB, NY, LF-022 *
14. Tinker AFB, OK, Bldg 3001
15. Tinker AFB, OK, Soldier Creek
16. Williams AFB, AZ, OU1 *
17. Williams AFB, AZ, OU2 *

* Closure installation

The RODs deal with a variety of contaminated media and represent a wide range of selected remedies, from No Action alternative to a $39,302,260 groundwater and soil cleanup. The costs of the selected remedies are shown in Table XIV. All costs are expressed in Present Worth using a 10-percent discount rate.

Table XIV, Summary of Selected Remedy Costs

ROD	SELECTED REMEDY COSTS
1. Castle AFB, Interim OU1	$42,354,608
2. Castle AFB, OU2	$3,776,000
3. George AFB, OU1	$9,083,267
4. Hill AFB, OU4	$9,583,742
5. Loring AFB, OU2	$25,412,400
6. Loring AFB, OU7	$2,009,100
7. Mather AFB, AC&W Site	$4,452,000
8. McClellan AFB, Interim OUB1	$3,172,000
9. Norton AFB, Central Base	$39,302,260
10. Pease AFB, Site 8	$14,525,219
11. Pease AFB, Zone 5	0**
12. Plattsburgh AFB, LF-022	$2,803,164
13. Tinker AFB, Bldg 3001	$21,526,440
14. Tinker AFB, Soldier Creek	$647,350
15. Williams AFB, OU1	$3,757,481
16. Williams AFB, OU2	$10,269,006*
TOTAL	$192,674,037

* The cost is estimate is a range of $10,269,006-$22,332,727.
** Cost of selected remedy is not given in the ROD.

The findings are based on the use of the best information available in the Records of Decision. It was not possible to validate each finding with a site visit. It may be possible that a specific finding may be inappropriate if additional information about the site was known. However, the purpose of the findings is not to present the best available treatment technology for each site, but instead to quantify savings that may be possible by restricting future land-use.

The reader is cautioned to take the effort as a whole and not focus on a specific installation, for which there may be a personal disagreement with the remedy selected by the author. Care has been taken to select an appropriate remedy that would protect human health without undue cost. Certain

engineering judgement also went into the selection of the remedy, such as always placing a cap on landfills, even though the results of the Risk Assessment did not find such necessary to protect human health.

What follows is a site-by-site analysis of the possible savings from implementation of land-use restriction. Hopefully, enough information about the site is provided the reader to explain the author's rational for his selected conclusions. Further information about individual sites are contained in Appendix F.

1. Castle AFB, OU1 - The Operable Unit is a TCE groundwater plume beneath the central portion or main sector of the base and contiguous areas to the south and southwest of the Base (57:3-1). Because of the interim nature of the ROD a complete characterization of the risks have not yet been completed.

The direction of groundwater flow takes the plume away from the industrial sector of the base where it appears to have originated and under residential areas. The land-use restriction scenario would not have a major impact on this cleanup effort since the contamination has reached residential areas. Residential areas are the most conservative type of land-use in respect to cleanup levels. A number of domestic water wells have already been abandoned due to TCE contamination.

Of the eight different treatment alternatives considered in the ROD only two are cheaper than the selected remedy

(57:7-7). The cheapest remedy, at $39,172,612, involves burning the air stripper emissions with a gas-fired thermal combustor. This is designed to destroy the contaminants and eliminate the need to dispose of such as off-site waste. There is concern, however, that this thermal treatment would not be accepted by either the State of California Department of Health Services or the community (57:7-7).

The next cheapest alternative at $39,833,728 uses ultraviolet photolysis to treat the granular activated carbon regenerant. EPA considers this to be an innovative treatment technology. Use of this alternative would result in a savings of $2,520,880 over the $42,354,608 selected remedy. This savings, however, is the result of using innovative treatment technologies and not from land-use restriction. A land-use restriction scenario as outlined in this research would not result in any savings to the selected remedy.

2. Castle AFB, OU2 - The Operable Unit is a TCE Plume in the area known as Discharge Area 4 and the Wallace Road Area. The contamination was originally detected during the sampling of local domestic wells in 1986 (58:14).

The Risk Assessment uses a future residential exposure for the development of the health risks. This classification as a future risk may be misleading. Residential exposure is also part of the current risk scenario since a military-quarters residential development is located on part of the site. Nine wells have already been impacted and six more are in the immediate vicinity (58:5).

The selected remedy is the least costly alternative next to an alternative that does not provide any treatment but instead provides for deed restrictions and an alternative water supply until natural attenuation takes care of the problem. This natural attenuation is estimated to take 50 years.

While the natural attenuation alternative will save a substantial amount of money the intent of this research is not to determine the cheapest possible method of cleanup. The groundwater is currently used as a source for domestic uses and, under land-use restriction, should continue to be allowed as a source of domestic water. Under land-use restriction, treatment of the groundwater would be needed and the selected remedy is the cheapest treatment alternative.

3. George AFB, OU1 - The Operable Unit is a groundwater TCE plume under the northeast portion of the base. The plume also extends across base boundaries to the north. Groundwater flow is to the northeast toward the Mojave River. Modeling predicts the plume will begin discharging into the Mojave River in 15 years at a maximum concentration of 10 ppb (59:2-19). The Mojave River near the base is generally a dry wash approximately 1 mile wide and is incised some 200 feet below the surrounding terrain (59:2-19).

The only wells known to exist in the path of the plume are the Victor Valley Wastewater Reclamation Authority wells that are not used to produce potable water (59:2-19).

The Risk Assessment encountered no current risk greater than 10^{-6}, since the groundwater in the area of contamination is not used as a potable water source. A future residential scenario assumes that a water supply well is placed at the center of the plume and, as used daily for 30 years, creates a cancer risk of $3.1X10^{-5}$ which is within the EPA's acceptable range of 10^{-4} to 10^{-6}. However, it is greater than the Cal-EPA acceptable level of risk of 10^{-6}. (59:2-2)

The land under the TCE plume and between the TCE plume and the Mojave River is not used for residential purposes. Between the TCE plume and the Mojave River is the Victor Valley Wastewater Reclamation Site. These sites are usually placed in industrial areas and not located near residential areas.

Restricting the use of this land to light industrial use would not have a major impact on the economy of the area. If one couples this land-use restriction with institutional controls to prevent the use of groundwater in the area for domestic use the risk to future residents is then reduced well below the 10^{-6} level and a Hazard Index of 1.0.

The use of land-use restriction would allow the selection of a groundwater monitoring option instead of the air stripping treatment called for in the selected remedy. The monitoring option would be $729,845 verses the $9,083,267 treatment option. This would result in a potential savings of $8,353,422.

4. Hill AFB, OU4 - The Operable Unit involves groundwater contamination in the upper 25 feet of the Shallow Aquifer. Primary groundwater movement is lateral and the contaminants have not migrated into the deeper aquifers. The site is located on a steep, naturally-terraced, north-facing escarpment. Groundwater flow in the shallow aquifer is to the north, discharging to off-base seeps along the north escarpment or to floodplain deposits of the Weber River (60:1-1).

The Risk Assessment found that shallow groundwater and seeps have TCE concentrations in excess of the Utah State MCL, but these are not used as sources of drinking water. The shallow groundwater because of horizontal groundwater movement has not affected the deeper aquifers and there is no risk associated with use of the deeper aquifers. (60:3-12)

The Risk Assessment concluded that all current risks to human health are well below levels considered by the EPA to be significant, with the greatest risk being a $2X10^{-7}$ cancer risk from inhalation of TCE soil gas by nearby residents (60:3-9).

A future residential scenario in the Risk Assessment exceeded the EPA target range for risks. This scenario assumed that the land-use around the site on Hill AFB would be changed from the current light industrial use to residential use and the residents would be supplied with water from the shallow aquifer, not the deeper aquifer which is the current

source of groundwater. The water for domestic use would also come from the most contaminated portion of the aquifer (60:3-6).

This is a situation where land-use restriction would save a substantial amount of remediation costs. There is no significant risk to human health from continued use of the land as it is currently being used. The risk comes into play with two important land-use changes. The first is that the area near the site is used for residential use and second that the shallow aquifer is used as a domestic water source.

Placing residential property near the site would mean placing housing off the northwest end of the base runway. This would not be considered a highly desirable location because of noise contours and aircraft flight paths. Becoming viable residential property, would require the abandonment of the base runway which is a multi-million dollar asset to the Air Force or future tenants of the property if the base should ever close in the future. With the areas to the north of the base only moderately developed residential areas separated by large tracts of agricultural land, the less desirable land at the OU site should not be under pressure to be developed as a residential site for the foreseeable future.

Limiting the use of the site and the area in the immediate vicinity to light industrial use therefore would have no major impact on the development of the base or the local economy.

Restricting the use of the shallow aquifer in the area to non-potable uses would also have no major impact on the development of the base or the local economy. The shallow aquifer is not currently used as a source of drinking water and is not anticipated to be used as a source in the near future.

Limiting the use of the area to light industrial uses and restricting the use of the shallow aquifer to non-potable uses would allow the selection of an alternative remediation remedy since significant future risks to human health would have thereby been eliminated.

The estimated $5,035,280 shallow-aquifer pumping and air stripping can be replaced with a groundwater monitoring program with institutional controls. The controls would restrict water rights and well drilling and obtain easements where monitoring is required. This would reduce the risk associated with future exposure since institutional controls would prevent the domestic use of the contaminated shallow aquifer. This alternative would cost an estimated $1,051,059, resulting in a potential savings of $3,984,221.

A similar program of institutional controls could be used in the areas where the hillside seeps are in sufficient quantity to provide surface water. The institutional controls would also provide fencing where the quantity is sufficient that consumption by livestock is a possibility. This would cost an estimated $294,542, as compared to the $353,584 for

collection and carbon adsorption treatment of groundwater in the selected remedy. This would equate to a $59,042 savings.

Access to the landfill could also be controlled with institutional controls, however it is not sound engineering to leave a landfill that is the known source of contamination to groundwater without installation of a final cover (cap). It is recommended by the author that either a clay-soil or multi-media cap be placed over the landfill to limit infiltration and reduce leaching of contaminants from the landfill contents. The cap would cost an estimated $2,705,683 and also involve revegetation and institutional controls to maintain its long-term integrity. This would result in savings of $1,293,577 over the $3,999,260 cap and vapor extraction system called for in the selected remedy. The air alternative called for in the selected remedy is a semi-annual air monitoring system in the basements of each local resident, at a cost of $196,287. This alternative would not change under land-use restriction.

The total potential savings from land-use restriction at Hill AFB, OU4 is $5,204,463.

5. Loring AFB, OU2 - The Operable Unit comprises the source control and soil remediation action for Landfill No. 2 and Landfill No. 3 on Loring AFB. The landfills are covered with six inches of native soil, installed in 1974 and 1991 respectively, but exposure pathways exist of surface water percolating down through the landfill to groundwater, leachate seepage up to surface water and fugitive dust (61:5-19).

The current risk of a child trespassing onto the site exceeded the Maine Department of Environmental Protection (MEDEP) standard of $1X10^{-5}$ at $6X10^{-4}$ for Landfill No. 2. The risk for future residential use exceeded $1X10^{-5}$ for both Landfill No. 2 and Landfill No. 3. (61:6-25)

The selected remedy for the site is to install a low-hydraulic conductivity composite cover system over the site coupled with deed restrictions for a cost of $25,412,400.

The ROD for the site only evaluated one alternative (selected remedy) beyond the No Action alternative. The No Action alternative is not a viable alternative since the current risk to the site exceeds the MEDEP standard.

While no other alternatives, other than the selected remedy, were evaluated in the ROD, there are other alternatives that could have been chosen that are more expensive than the final cover system chosen. In fact, placing a final cover system on a landfill is good sound engineering practice even if the current risk of the landfill is low.

There are no potential savings through the use of land-use restriction at Loring AFB, OU2.

6. Loring AFB, OU7 - This Operable Unit addresses contaminated soil and sediment of a quarry approximately 800 feet east of the western border of the base. The seven-acre site served as a source of limestone rock for construction and expansion of the base from 1947 to 1985. Historically, waste materials from construction projects, industrial and

maintenance shops, and other base activities were stored at formerly-mined portions of the site. (62:2-1)

The Risk Assessment identified contaminants in the soil and sediment also from the wetland adjacent to the site. The Risk Assessment found both the current and future land-use exposure scenarios to result in risks above the MEDEP standard of $1X10^{-5}$ (62:6-8). This means that a cleanup alternative is necessary even under land-use restrictions as outlined in this research.

Of the alternatives considered in the ROD, the selected remedy of excavation of wastes and contaminated soil/sediment and use of as a subgrade material for the landfill cap on OU2, has the lowest cost. This innovative approach is using one problem to help solve another problem and saving money in the process.

Use of land-use restriction does not have the potential of saving money over the selected remedy at Loring AFB, OU7.

<u>7. Mather AFB, Aircraft Control & Warning Site</u> - The Operable Unit consists of TCE in the shallow groundwater at 4 ppb to 790 ppb. No significant soil contamination has been yet found. Most of the groundwater production wells are at depths greater than 318 feet below land surface. (63:2-7)

Modeling during the Risk Assessment predicted that the TCE plume is not expected to impact downgradient drinking water wells in the future and that natural attenuation may reduce the maximum exposure concentration to 5 ppb within 20 years (63:2-24).

The Risk Assessment concluded that there is no current risk since the groundwater does not currently present a pathway for exposure. A hypothetical unrestricted residential land-use with new drinking wells installed in the shallow aquifer would create an excess cancer risk of $1.1X10^{-5}$ (63:2-33). This is still within the EPA target range of 10^{-4} to 10^{-6}.

The selected remedy of extraction and air stripping would require an estimated 10 years, at a cost of $4,452,000.

Institutional and access restrictions would prevent the use of the shallow aquifer as a drinking water source and eliminate this future exposure pathway. This would eliminate the future risk to the site. The cost of these restrictions would be approximately $508,800. This would represent a savings of $3,943,200 over the selected remedy, a significant savings benefiting from land-use restriction.

<u>8. McClellan AFB, Interim OUB1</u> - The site is located on the southwest portion of the base and consists of an open storage lot operated by the Defense Reutilization and Marketing Office (DRMO); a former transformer storage, loading, unloading area; the Civil Engineering (CE) Storage Yard; and three drainage ditches that receive surface water runoff from the DRMO storage lot (64:II-1).

Testing found polychlorinated biphenyl (PCB), dioxins, furans, petroleum hydrocarbons, volatile organic compounds, semi-volatile organic compounds, and inorganics in the soil, primarily in the near surface (64:II-9).

The Risk Assessment found the current risk to workers is $3.8X10^{-4}$, above the EPA acceptable risk level of 10^{-4} (64:II-33). The selected remedy consists of capping the site with two-inches of asphaltic concrete over engineered fill and conducting future treatability studies on possible contaminate destruction technologies, at a cost of $3,172,000. The cap sufficiently reduces the current risk at the site and the treatability studies explore possible means of removing or reducing the contamination in the future.

Under land-use restriction the treatability studies would not be necessary since the cap eliminates all surface exposure routes. This means that a cap-alone alternative could be chosen at an estimated cost of $2,684,000, resulting in a potential savings of $488,000.

9. Norton AFB, Central Base - The site involves TCE in groundwater and TCE and chromium in the soil in the central part of the base. The plume is moving in a southwest direction toward the Santa Ana River and several water supply wells. Three of these wells consistently detect TCE in the water (65:5-1). The current and future risks from groundwater and soil range from $3.8X10^{-3}$ to $5.3X10^{-5}$ using the Cal-EPA risk assessment procedures. The risk of just the groundwater ranges from $1.6X10^{-5}$ to $6.9X10^{-5}$ (65:6-3).

The groundwater is currently used as a source of drinking water. Land-use restriction as defined in this research would not prevent its continued use. The upper water-bearing zone of the aquifer already has been affected. To reduce the risk

to human health the groundwater must be treated for continued use as a drinking supply. Analysis also indicates contaminated soil as the contamination source which also must be dealt with.

The lowest cost treatment alternative was only selected for groundwater treatment; lower-cost treatments are available for the soil. Savings from the selection of these alternative would not be associated with land-use restrictions.

Implementation of land-use restriction would not result in any savings over the selected remedy.

10. Pease AFB, Site 8 - The site is a former fire training area located on the northern portion of the base, and active from 1961 to 1988 (66:6). The soil within 500 feet of the area and approximately 30 feet deep is contaminated with organic compounds (66:18). A plume of free-phase products (LNAPLs) floating on the groundwater surface. There is a second plume of dissolved contaminants that extends from the former burn area across the base boundary and under Newington Town property, in the vicinity of a number of dwellings with wells and/or springs in active use (66:2).

The Risk Assessment used a future scenario wherein the base was assumed to continue in a civilian industrial role. The future risk to off-base residents was found to be $4X10^{-5}$ or $3X10^{-3}$ from using groundwater in the overburden soils or from bedrock respectively. The Hazard Index from this groundwater use is also 20 and 40 respectively. (66:E-37)

The selected remedy consists of soil vapor extraction (SVE) for the contaminated soil and the construction of a Groundwater Treatment Plant (GWTP) at an estimated total cost of $14,525,219.

There might be a chance to achieve additional potential savings by use of containment of contaminated soil verses the selected SVE treatment. This savings however is a result of selecting a different treatment remedy rather than from land-use restriction. The assumption in the Risk Assessment that the future use of the base was to remain industrial, a form of land-use restriction incorporated into the site cleanup process. This land-use restriction was not based on future institutional controls but instead on the reasonable expectations on the future use of the land instead of automatically defaulting to a worse-case scenario in which future residential use is assumed.

11. Pease AFB, Zone 5 - This involves a Construction Rubble Dump and the Fuel Maintenance Squadron Equipment Cleaning Site. The Risk Assessment concluded that no unacceptable adverse health effects will result from incidental ingestion of, or dermal contact with, contaminated soil, sediment, or surface water (67:45). Cancer risks are within EPA's acceptable risk range of 10^{-4} to 10^{-6}, and Hazard Indices are less than 1.0 (67:43).

The selected remedy for the site is a "No Action" remedy, with long-term monitoring. The cost of this long-term monitoring was not given in the ROD. A cost estimate for

long-term monitoring at the site was not developed by the author since it is not necessary in determining a cost savings under a land-use restriction scenario.

The selected remedy is the least costly alternative and no cost savings would be encountered at this site from land-use restriction.

12. Plattsburgh AFB, - The site is an old base landfill. All risks from the current use of the land are below 10^{-6} and the Hazard Index is below 1.0. Carcinogenic risks to a future off-base resident are calculated at between $6X10^{-6}$ and $1X10^{-5}$. This falls within the EPA target range of acceptability. The noncarcinogenic risk for a hypothetical child resident is 2.0. Most of the elevated Hazard Index is associated with the ingestion of manganese in the groundwater. The Risk Assessment concludes that this does not indicate a significant risk to human health under current or future site conditions. (68:6-11)

The finding of no significant health risk makes the Plattsburgh AFB LF-022 site a potential candidate for a "No Action" remedy. Remember No Action usually does not mean no cost, since a 30-year monitoring program is always required by EPA, and also required by New York State Solid Waste Management Facility Regulations. The cost of this monitoring is estimated as $896,376. This would mean a savings of $1,906,788 over the $2,803,164 selected remedy.

The selected remedy involves site grading and creating a grass cover to enhance evapotranspiration. The selected

remedy is a good cost-effective method to reduce potential contaminant migration, while avoiding the high cost of a low-hydraulic conductivity final cover that would cost an additional $6,712,212.

It is the opinion of this author that the selected remedy should be accomplished at Plattsburgh AFB LF-022 site even under a land-use restriction scenario.

13. Tinker AFB, Building 3001 - The site is near the northeast border of the base and consists of a groundwater plume under building 3001 and a down-gradient area of approximately 220 acres (69:1). The primary contaminants of concern in the plume are TCE and chromium, largely from electroplating activites associated with renovation of aircraft parts. The plume is currently in the upper horizons of the aquifer, but left untreated, will migrate downward to the producing level of the aquifer. There are 25 water supply wells located on Tinker AFB, in the down-gradient area of the site (69:16).

The Risk Assessment scenario of drinking contaminated groundwater over a 70-year exposure period equates to a risk of $1.2X10^{-5}$, within the acceptable EPA range of 10^{-4} to 10^{-6} (69:31).

The Risk Assessment concluded the carcinogenic risk to be "low", and therefore the site is a potential candidate for the No Action alternative. However, one of the nine SARA evaluation criteria (page 9) is compliance with Applicable, Relevant, and Appropriate Regulations (ARARs), such the Safe

Drinking Water Act (SDWA) regulations. The relevant Maximum Contaminant Levels (MCLs) for drinking water is 5.0 ppb for TCE. The exposure concentration of TCE in the groundwater is 16.7 ppb and the aquifer is the major source of drinking water for the area. Selection of "No Action" does not comply with SDWA. Instead the selected remedy incorporates air stripping, metals-removal by PH adjustment/precipitation, and fine filtration, for a total cost of $21,526,440. This is at a site where the risk to human health is considered "low".

There could be considerable savings generated at this site but it would require an ARAR waiver. This would not be the results of land-use restriction. There is no potential savings at the Tinker AFB, Bldg 3001 site from land-use restriction.

14. Tinker AFB, Soldier Creek - The site involves the sediment and surface water of Soldier Creek, which is to the east of Tinker AFB and used primarily for aesthetics and limited recreation. Volatile organics, semi-volatile organics and inorganics were detected in the sediment and surface water of the creek (70:5-8).

The Risk Assessment determined all noncarcinogenic risks are represented by a Hazard Index of less than 1.0 and all carcinogenic risks are less than $1X10^{-6}$, therefore the sediment and surface water do not present a treat to human health (70:6-16).

The lack of risk makes the site a prime candidate for the "No Action" alternative, requiring only a statutory five-year

review, at an estimated cost of $14,157. This would result in a savings of $633,193 over the selected remedy. This alternative would not track whether the contamination was increasing or decreasing. The actual source of the contamination was not determined and could have come from one or more of 14 underground storage tanks and solvent disposal pits or past industrial plumbing cross-connections. The contamination could be from service stations, a salvage yard, auto repair shop, or paint shop not located on Tinker AFB but are within the Soldier Creek drainage system.

The selected remedy includes quarterly groundwater and sediment sampling for the first two years and semi-annual sampling during the last three years, to ensure that no unacceptable exposures occurred. This monitoring, while not required, is sound environmental engineering practice. It is the opinion of the author, that while the No Action alternative would save money, the selected remedy is the most appropriate alternative.

<u>15. Williams AFB, OU1</u> - The Operable Unit incorporates ten individual sites, known as various Underground Storage Tanks, Hazardous Material Storage Area, Pesticide Burial Area, Radioactive Instrument Burial Area, drainage system, Fire Training Area, and Landfill. The Risk Assessment found all sites but the landfill to have cancer risks less than 10^{-4} and Hazard Index to be less than 1.0 (71:5-2). The Risk Assessment concluded that no further action was necessary at these sites.

The Risk Assessment found the landfill to have a soil-ingestion Hazard Index of 1.21 for both current and future residents (71:5-20). The selected remedy is to install a permeable final cover over the contaminated soil and imposing land-use restrictions to protect the integrity of the cover at an estimated cost of $3,757,481.

Placing a cover over the landfill is not only sound environmental engineering practice, but is also necessary to reduce the risk to current residents. Land-use restrictions are implemented to protect the cover and prevent future risk to residents. This is an example where land-use restrictions are being implemented as an integral part of the selected remedy, to help eliminate future risks.

16. Williams AFB, OU2 - The Operable Unit is located at the base's Liquid Fuels Storage Area and defined as the groundwater and the uppermost 25 feet of soil (72:1-1). The potential risk to human health is from groundwater and soil contaminated from JP-4 fuel.

There are currently no production wells in the contaminated area. Groundwater modeling indicates that potential future migration of the chemicals is not expected to affect any existing base production wells. The area is currently fenced, the potential for a trespasser to contact this area is extremely low. The greatest current risk is $5.9X10^{-6}$ cancer risk from occupational ingestion of soil (72:5-8). This is within the EPA target level of 10^{-4} to 10^{-6}. There

is a $2.5X10^{-6}$ cancer risk from naturally occurring beryllium in the surface soil (72:5-8).

Under future residential use there is a cancer risk of $6X10^{-5}$ associated from benzene in the drinking water and a total Hazard Index of 12 (72:5-9). This exceeds the standard index of 1.0.

The selected remedy for the site includes free-phase product and groundwater extraction, air stripping, pre-and post-treatment as needed, bioenhanced soil vapor extraction (SVE) for the first 25 feet of soil depth, and treatment of vapors at an estimated cost that ranges from $10,269,006 to $27,332,727 depending on the type of extraction wells used and the method of treating the off-gased vapors. The selected remedy will also include restrictions on installations of new wells and limits soil excavations to 10 feet in depth. The groundwater remediation is expected to take 30 years.

An alternative to the selected remedy for example, could include deed restrictions on future land-use coupled with the restrictions on construction of new wells. This Alternative would include periodic monitoring of wells. A cover would be constructed over the contaminated soil to prevent ingestion by potential receptors.

This Alternative would also provide a means of protecting the public from exposure to the contaminated groundwater by restricting use of the aquifer. There is the potential that the contaminants will spread to additional portions of the aquifer. This can be evaluated through the periodic

monitoring. There is also the possibility that natural attenuation will ultimately result in groundwater that meets acceptable quality.

There exists the presence of significant volumes of contaminated soil below the 25-foot level, that represent a potential source of long-term groundwater contamination. This soil is being dealt with in another Operable Unit. Spread of contamination or natural attenuation may be impacted by this other Operable Unit.

This Alternative would also prevent exposure to surface and subsurface soils. The cost of this Alternative would be an estimated $2,932,524. This would result in a savings of at least $7,336,482 and could range up to $24,400,203 depending on the type of extraction wells and vapor treatment Technologies making up the selected Alternative.

Of the 16 environmental cleanup sites, only five were found to have significant savings from land-use restriction as shown in Table XV. This savings totals $25,325,567 or 13 percent of the original remediation total. This is a conservative estimate as explained in the methodology. The identified savings at individual sites ranged from zero to 92 percent.

When the savings are extrapolated, by the author, over the entire 4,970 Air Force hazardous waste sites there is the potential of $828,100,000 savings for the Air Force or $3,900,000,000 for the entire Department of Defense.

Table XV, Potential Savings from Land-use Restriction

ROD	SAVINGS FROM LAND-USE RESTRICTION
1. Castle AFB, Interim OU1	0
2. Castle AFB, OU2	0
3. George AFB, OU1	$8,353,422
4. Hill AFB, OU4	$5,204,463
5. Loring AFB, OU2	0
6. Loring AFB, OU7	0
7. Mather AFB, AC & W Site	$3,943,200
8. McClellan AFB, Interim OUB1	$488,000
9. Norton AFB, Central Base	0
10. Pease AFB, Site 8	0
11. Pease AFB, Zone 5	0
12. Plattsburgh AFB, LF-022	0
13. Tinker AFB, Bldg 3001	0
14. Tinker AFB, Soldier Creek	0
15. Williams AFB, OU1	0
16. Williams AFB, OU2	$7,336,482
TOTAL	$25,325,567

B. SURVEY FINDINGS

In addition to quantitative figuring of the potential savings from land-use restrictions a survey was sent to Air Force base-level environmental managers, as outlined in the methodology, to obtain their subjective opinion on cost savings measures. A total of 64 surveys were received for a 80 percent return rate. In addition to answering the survey, 15 respondents provided candid comments on a number of issues involved in hazardous waste remediation. These comments are contained in Appendix E.

One area of the survey asked the respondents to rank-order five cost savings measures. The ranking had 1 being the greatest potential for cost savings. The average ranking of the measures by the respondents is shown in Table XVI. "Realistic Risk Assessments" was ranked the highest by a substantial margin. A definition of a Realistic Risk

Table XVI, Ranking of Potential Cost Savings Measures

	Average Ranking
1. Realistic Risk Assessment	1.72
2. Land-use Restriction	2.80
3. Standardized Cleanup Levels	3.24
4. Increased Use of Containment	3.45
5. Emerging Innovative Technologies	3.56

Assessment was not given to the respondents. What is clear from the results is a great number of the respondents do not feel the current Risk Assessment process is realistic. Land-use restriction was ranked second among the five cost savings measures. This ranking order also held true when the respondents were asked to quantify the amount of savings possible by selecting among a range of values. The respondents were asked to select a choice that represented a range of possible savings. The average response fell between a response number "7", that equates to a 26-30 percent savings range, and a response number "8", that equates to a 31-40 percent savings range. Land-use restriction had an average response falling between a response number "5", that equates to a 16-20 percent savings range and a response number "6", that equates to a 21-25 percent savings range. The value of the average response is shown in Table XVII. The range of 16-25 percent is not far off from the 13 percent calculated savings obtained from the environmental RODs. Remember the 13 percent is a conservative estimate with acutal savings possibly higher.

Table XVII, Response to Amount of Potential Savings from Cost Savings Measures

	Average Response*
1. Realistic Risk Assessment	7.76
2. Land-use Restriction	5.82
3. Emerging Innovative Technology	5.63
4. Increased Use of Containment	5.20
5. Standardized Cleanup Levels	5.19

* 5 = 16-20 percent savings   7 = 26-30 percent savings
  6 = 21-25 percent savings   8 = 31-40 percent savings

The response the environmental managers gave the ranking of land-use restriction and the quantification of the potential savings was analyzed using Chi-square statistical test. The test was performed to see if there was any correlation between the responses to the questions and the Air Force Major Command, number of years working with IRP, number of sites at the installation, or the progress of sites on the installation toward remediation. The results of the Chi-square testing of these variables and the ranking of Land-use restriction is given in Table XVIII. The result between the

Table XVIII, Chi-Square Results of Correlation between the Ranking of Land-use Restriction and other Variables

	p
Major Command	.211
Number Years Working with IRP	.423
Number of IRP Sites at the Installation	.510
Progress of Sites toward Remediation	.334

variables and the response to the potential saving possible from land-use restriction is given in Table XIX. The actual data and matrix tables are given in Appendix D.

Table XIX, Chi-Square Results of the Potential Correlation between the Response to Amount of Savings Possible with Land-use Restriction and other Variables

	p
Major Command	.236
Number of Years Working with IRP	.396
Number of IRP Sites at the Installation	.595
Progress of Sites toward Remediation	.158

Chi-square testing found no basis for rejecting the null hypothesis that there is independence between the variables at the 90-percent confidence level. The lowest probability was .158, as obtained between the progress of sites on the installation toward remediation and the potential savings resulting from land-use restriction. Between these two variables, 15.8 percent of the time, that value of Chi-square could be obtained from two totally independent variables. These high percentages provided no basis for determining any dependence between the variables.

C. COMPLIANCE WITH CERCLA AND IRP PROCEDURES

The review of CERCLA and SARA wording uncovered some restrictions that would apply to the use of land-use restrictions at IRP sites for closure bases. Section 120(h)(3)(B) of SARA states:

a covenant warranting that

> (i) all remedial action necessary to protect human health and the environment with respect to any such substances remaining on the property has been taken before the date of such transfer, and
> (ii) any additional remedial actions found to be necessary after the date of such transfer shall be conducted by the United States. (56:935)

This statement by itself does not eliminate any hope of land-use restrictions at closure bases, but it does appear to leave the liability remaining with the United States or the responsible agency (Air Force). This removes a large portion of the incentive for land-use restriction since the Air Force would not be in a position to enforce the restriction but would still be liable for the substances that the land-use restrictions are meant to isolate or contain. The section further describes the remedial action as the completion of construction and installation of an approved remedial design and demonstration that it is operating properly and successfully.

In Section 101(24) it describes what is meant in the law by remedial actions:

> The terms "remedy" or "remedial action" means those actions consistent with permanent remedy taken.... The term includes, but is not limited to, protection using dikes, trenches, or ditches, clay cover.... (56:862)

Cost effectiveness was an original intent of CERCLA. Section 121 (a) states:

> The President shall select appropriate remedial actions determined to be necessary to be carried out under Section 104 or secured under Section 106 which are in accordance with this section and to the extent practicable, the National Contingency Plan,

> and which provide for cost-effective response. In evaluating the cost effectiveness of proposed alternatives remedial actions, the President shall take into account the total short and long-term costs of such actions, including the costs of operation and maintenance for the entire period during which said activities will be required. (56:939)

This cost-effectiveness emphasis has been overshadowed by calls for permanence with the 1986 passage of SARA. Section 121(b)(1) says:

> Remedial actions in which treatment which permanently and significantly reduces the volume, toxicity or mobility of the hazardous substances, pollutants, and contaminants as a principal element, are to be preferred over remedial actions not involving such treatment. (56:940)

This preference for permanence is so strong that Section 121(b)(1) further states:

> The President shall select a remedial action that is protective of human health and the environment, that is cost effective, and that utilizes permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. If the President selects a remedial action not appropriate for a permanence under this subsection, the President shall publish an explanation as to why a remedial action involving such reductions was not selected. (56:940)

While CERCLA does not specifically disallow land-use restrictions it gives overwhelming preference for permanence. It is the opinion of the author of this research that land-use restrictions could be held to violate the intent of CERCLA through a reduced emphasis on permanence. However, land-use restriction could be interpereted as a remedial action that permanently and significantly reduces the volume, toxicity, or

mobility of the waste. If given this interpretation it would clearly fall within the guidelines of CERCLA.

Whether land-use restrictions were part of the original intent of CERCLA or not it has clearly found its way in the EPA guidance implementing the law. For example, the EPA guidance for conducting Feasibility Studies shows an example screening of technologies. Listed on this example is Deed Restrictions which is a method of land-use restriction. Under the screening comments it lists the words "Potentially applicable." (6:4-17) This clearly demonstrates to those conducting Feasibility Studies that Deed Restrictions should be considered as a possible Alternative.

Since land-use restriction is not specifically disallowed in CERCLA and is even mentioned in guidance (31:4-17) implementing the law, it must be concluded that land-use restriction is in compliance with CERCLA and SARA.

While CERCLA requires the cleanup of property prior to transfer or sale, there is not the same restriction on leasing. The DOD has issued guidance which allows the lease of property under conditions where the property contains some relatively low level of contamination. The property may be leased and used for the purpose in the lease with use restrictions specified, providing an acceptable level of risk to human health or the environment (8:F6). At Pease AFB in New Hampshire, an Air Force closed installation, 1,700 acres of land was transferred from the Air Force to the state designated development authority on a 55-year lease. As part

of the lease, the Federal government accepted environmental responsibility for the site (73:30). The Pease AFB lease did not reduce environmental cleanup cost but was used as a method to speed reuse. The lease procedure is a viable method to implement land-use restrictions while avoiding the CERCLA preference for permanence. This approach would be able to capitalize on the potential savings of land-use restriction while allowing the base to be reused in an expeditious manner.

An analysis of the current CERCLA reauthorization proposal reveals that any intent to avoid intitutional controls as part of the remedy selection process has been eliminated. The proposal reads:

> The President shall consult with the CWG [Community Working Group] on a regular basis throughout the remedy selection process regarding the reasonably anticipated future use of land at the facility and any institutional controls required to assure that land use determinations remain in effect. (74:15)

In fact it later discusses the types of restrictions that might be considered:

> Whenever the President selects a remedial action which relies on restrictions on the use of land, water, or other resources to achieve protection of human health and the environment, the President shall specify the nature of the restrictions required to achieve such protections, including restrictions on the permissible uses of land, prohibitions on specified activities upon the property, restrictions on the drilling of wells or the use of ground water, or restrictions on the use of surface water,.... (74:205)

From this wording, it is clear that Congress intended land-use restrictions as a definitely viable option under the CERCLA reauthorization proposal.

D. PROCEDURAL FINDINGS

Procedurally, land-use restriction options can be easily incorporated into the current CERCLA process. Currently, during the Exposure Assessment portion of the Risk Assessment two basic exposure settings are explored. These two settings are the current exposure (land-use) and the future exposure (land-use). In determining the future exposure the process often defaults to a residential exposure scenario. This does not have to be the case. As an example, in the Risk Assessment for Pease AFB, Site 8, the future land-use within base boundaries was assumed to continue as industrial. This is a reasonable assumption at almost every Air Force base. But rather than always make this assumption, a third exposure setting, future exposure with current land-use, can easily be explored. This would result in a modified Exposure Assessment as shown in Figure 9.

Addition of this third setting to the Exposure Assessment allows sufficient information to be obtained to provide decision makers the opoortunity to consider land-use restriction as a viable option during the remedy selection process. This allows decision makers to clearly have full knowledge of the impact of land-use restrictions on protecting the public's health and reducing cleanup costs.

The major benefit to this modified procedure is that it does not ignore the possiblity of restricted land-use during the Risk Assessment and also does not require an assumption that future land-use will not change. It instead, provides

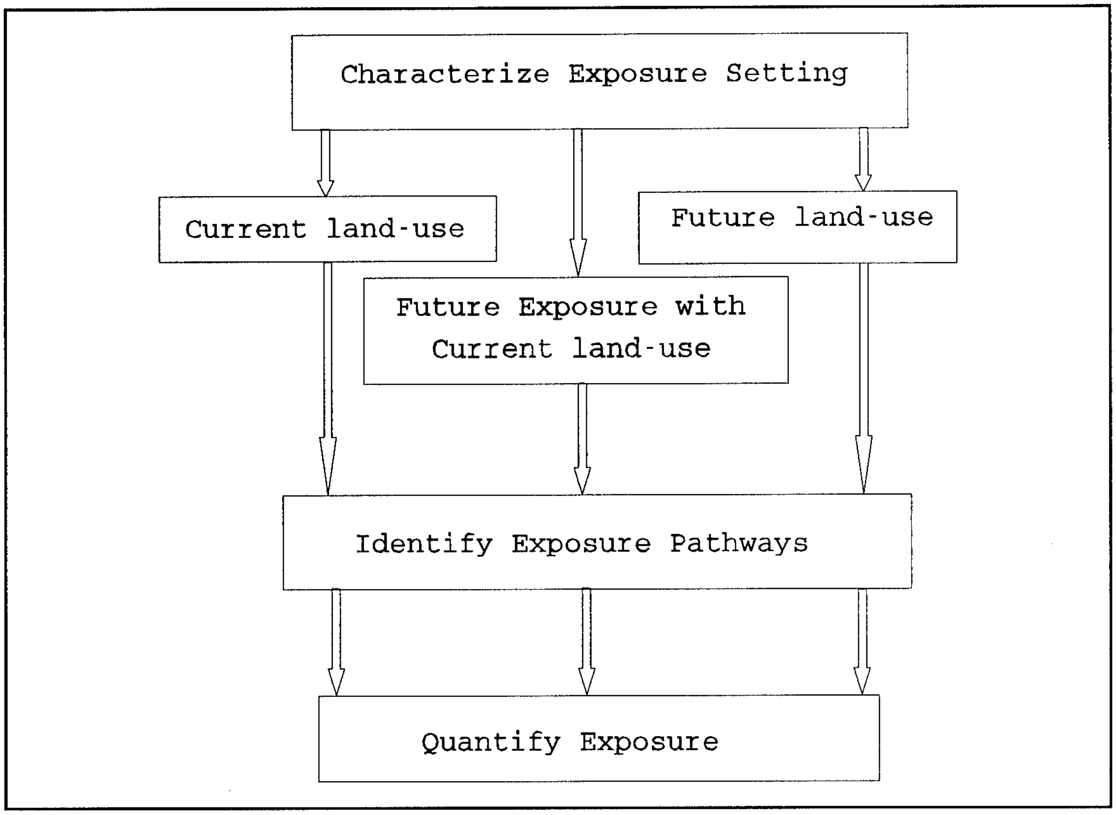


Figure 9, Modified Exposure Assessment

decison makers with sufficient information to consider the full range of options available. A selection of land-use will be able to be based on its impact and merits.

V. CONCLUSIONS AND RECOMMENDATIONS

A. RESEARCH QUESTIONS ANSWERED

Four research questions were presented in Section I of this dissertation. In this section, each of the four questions are reiterated along with a brief summation of their respective answers.

Two of the questions deal with the cost savings possible from land-use restriction and two deal with the implementation of land-use restriction options.

1. Cost Savings - The first research question posed in this dissertation was, "What are the potential cost savings to Air Force hazardous waste remediation costs by restricting future land use to current land use?" Limiting the use of the land to its current use will save a significant amount in the cleanup of hazardous waste sites. The calculated savings was 13 percent over the 16 sites analyzed. The entire savings came from five sites with 11 sites gaining no savings. This estimate is considered conservative with actual savings possibly higher. Additional savings would also be possible from the selection of a lower cost alternative than the selected remedy. Table XX shows where the selected remedy ranks in relation to cost among the remedies considered. The No Action alternative was not considered as a viable alternative when preparing Table XX.

A good indicator to see if significant savings are possible is to check the risk to current use. If the current

Table XX, Ranking of Alternatives by Cost

	# of Remedies Considered*	Ranking of Selected Remedy (1-Most Expensive)
1. Castle AFB, Interim OU1	8	6th
2. Castle AFB, OU2	5	4th
3. George AFB, OU1	2	2nd
4. Hill AFB, OU4		
Groundwater	4	2nd
Surface Water	4	3rd
Soil	4	2nd
5. Loring AFB, OU2	1	1st
6. Loring AFB, OU7	3	3rd
7. Mather AFB, AC&W	10	6th
8. McClellan AFB, OUB1	6	5th
9. Norton AFB, Central Base		
Groundwater	2	2nd
Deep Soil	2	1st
Shallow Soil	3	2nd/3rd**
TCE & Chromium Soil	2	2nd
10. Pease AFB, Site 8	7	4th
11. Pease AFB, Zone 5	0	
12. Plattsburgh AFB, LF-022	2	2nd
13. Tinker AFB, Bldg 3001		
Pumping	2	1st
Treatment	4	1st/2nd (tie)
Pit Contents	2	1st
14. Tinker AFB, Soldier Creek	5	5th
15. Williams AFB, OU1	1	1st
16. Williams AFB, OU2	3	2nd

* The No Action alternative was not counted as an alternative

** Different alternatives selected for different areas of the site

risk is less than the acceptable 10^{-4} to 10^{-6} range, then chances are likely that significant savings are possible. This was the case in the 16 RODs analyzed. Five sites had current risks less than 10^{-6}. Three of these five sites account for 69 percent of the total savings. The other two sites have potential savings but are recommended to stay with the treatment remedy selected. One site is a landfill with

the selected treatment a cap on the landfill. Selection of this remedy is based on good engineering practice. The other site's selected remedy involves a monitoring program. This remedy would also fall into the category of good engineering practice.

The 13 percent savings equates to over $25 million. If this same savings level was extrapolated through all DOD hazardous waste sites the savings would approach $4 billion.

The second research question asked, "Are the cost savings significant enough to implement?" The savings from land-use restrictions are significant, but as discussed in the Literature Review, it is necessary to consider the costs as well as the benefits. The cost to achieve the land-use restriction savings is the land will no longer have unlimited use. This is not a significant cost for those bases that are remaining in the possession of the Air Force. The Air Force will be able to continue to use the land as it is presently. But, what about the closure bases that will be transferred to communities? Is this a significant cost impact on these communities? The goal of these communities is to get this land back into productive use, generating jobs and revenue for the communities. This is necessary to compensate for the jobs and revenue lost from the closure.

Land-use restriction should not hamper the redevelopment of closure bases significantly. Local governments and the private sector are and will continue looking for industrial firms and businesses to create the jobs necessary to replace

those lost during the closure. It is unlikely that the future use of the bases would be significantly different than the current use. It is doubtful that communities will want to demolish runways, hangers, and warehouses to create areas for single family dwellings. Those areas that will be used for residential purposes are those portions of closure bases that were used by the military for housing. These housing units will probably be retained as housing. One use for these housing units is homes for the homeless. Under the 1987 McKinney Act, the homeless are given priority for surplus government property (75:15). The industrial portions of the base will most likely remain industrial. As an example, at Bergstrom AFB in Austin, Texas the city is looking to convert the base to a new municipal airport (75:15). At Plattsburgh AFB in upstate New York, they are looking to attract a foreign company looking for a U.S. address to do business (75:15). Williams AFB in Arizona is approved to be converted into a commercial airport and education and training complex (75:15). Land-use restriction would not hamper any of these proposed developments.

2. Implementation - The third research question asked, "Can the future land-use restriction savings be realized under current CERCLA and IRP procedures?" Land-use restrictions are not mentioned specifically in the wording of CERCLA and SARA. Whether restrictions were part of the original intent of these laws is unclear, but land-use restrictions have found their way into EPA guidance implementing CERCLA. It is unlikely

that land-use restriction will be eliminated in the near future. The reauthorization proposal H.R. 4916 specifically mentions land-use restrictions as a remedial action to be considered. The answer to the third research question is a yes, land-use restriction is possible under current CERCLA and IRP procedures.

The final research question asked, "What procedural or regulatory changes are necessary if any to implement future land-use restriction criteria?" To fully implement and benefit from this potential cost savings, during the risk assessment process three separate exposure settings need to be considered. One for current use, one for unrestricted future use, and the other for restricted future use. The finding from these exposure settings can then be used in the Feasibility Study to fully explore land-use restrictions as a viable remedy option. This process will then give the decision makers sufficient and adequate information to make an informed decision. This will help make the Record of Decision a resource allocation decision rather than a decision in which costs play a minor role.

B. FURTHER RESEARCH AND COMMENTS

The Air Force base closure and transfer process and the associated environmental cleanup operates in a political arena. This research has not addressed the political nature of this process but has been restricted to the quantitative determination of potential savings. There are some basic

questions that need to be considered if these savings are ever to be achieved? These questions include:

> Is the Air Force willing to adopt this approach as a valid cost savings measure?
>
> Will regulatory agencies accept this approach?
>
> Will communities accept or reject this approach?

The administration's reauthorization proposal on Superfund is an indication that this type of approach is gaining support and being accepted as an acceptable alternative. Further research could develop an implementation plan to be used to take the plan from the theoretical stage to the reality stage.

The Air Force laboratories are conducting extensive research on new and emerging technologies in hopes of finding ways to perform cleanups faster, cheaper, and more efficiently. This research has made considerable progress and shows great potential. However, the cleanup requirements are all based on the risk assessment. The current risk assessment process uses estimates, assumptions, and engineering judgement. With so much money involved in hazardous waste cleanup there needs to be improved methods of determining what cleanup is required and to what level. The government spent $37 million to evacuate the residents of Times Beach. The federal official that urged the evacuation now says he made a mistake, it was not necessary. Billions of dollars have been spent to clean up dioxin throughout the country, now the evidence shows that it is not nearly as harmful as originally believed. With so much of the cost of cleanup contingent on the risk assessment, it may not have been given the attention

it deserves. An area of further research would be an analysis of EPA's risk assessment process. Does the estimating techniques comply with commonly accepted practices? What is the cumulative result of the conservative estimates?

While it is possible to save money on hazardous waste cleanup by restricting land-use, there is also the counter feeling that this approach is allowing permanent damage and scars to be left on the land that will restrict its use by future generations. This can not be viewed as actions of good stewards of the environment.

To allow contamination of the environment to have occurred and not to make the organization responsible fully cleanup the contamination may not seem rational to many people. However, this research bears in mind that there are costs and benefits associated with all actions and is the millions of dollars spent on cleaning up a site beyond the level that effects human health warranted. Where the costs do not directly impact on an individual it is easy to make a value judgement that the additional money should be spent since there is no direct cost to the individual. Many people view this as the situation involving Department of Defense property as well. It must be remembered that the cost of cleanup at DOD property is born by the American taxpayer directly as increased taxes or indirectly as reduced national defense. Is the taxpayer willing to pay this cost? This research does not attempt to answer that value judgement, but instead has attempted to realistically present the potential

savings that may be possible by simply restricting future land-use at contaminated sites to the current land-use.

Society and lawmakers are realizing more and more that there are more government programs than taxpayer's money to go around. Tough choices have to be made on the priority of programs and the payback or results received for the money spent. Governmental environmental cleanup has been an area of spending that has increased over the years. It is one that will continue to increase unless significant changes are made to the program.

Probably the greatest need for further research is expressed by the Air Force base level environmental managers in some of their written comments contained in Appendix E. These individuals are not concerned with theoretical findings, but are concerned with reasonable solutions to real problems. Hopefully, this research will be able to find its way from a theoretical finding to becoming a reasonable solution to the real problem of Air Force hazardous waste sites.

APPENDIX A

DEFINITIONS/ACRONYMS

ACRONYMS

AC&W - Aircraft Control and Warning

AFB - Air Force Base

ARAR - Applicable, Relevant and Appropriate Regulations

CAL-EPA - California Environmental Protection Agency

CERCLA - Comprehensive Environmental Response, Compensation and Liability Act

CERLIS - Comprehensive Environmental Response, Compensation and Liability Information System

CFR - Code of Federal Regulation

CMS - Corrective Measures Study

CONUS - Continental United States

CPC - Contaminant of Potential Concern

CWA - Clean Water Act

DDD - Dichlorodiphenyldichloroethane

DDE - Dichlorodiphenyldichloroethene

DDT - Dichlorodiphenyltrichloroethane

DERA - Defense Environmental Restoration Account

DERP - Defense Environmental Restoration Program

DOD - Department of Defense

DOE - Department of Energy

EIS - Environmental Impact Statement

ENVEST - Environmental Estimating

EOA - Environmental Oversight Agreement

EPA - Environmental Protection Agency

FIFRA - Federal Insecticide, Fungicide and Rodenticide Act

FS - Feasibility Study

GWTP - Groundwater Treatment Plant

HDPE - High Density Polyetheylene

HI - Hazard Index

HRS - Hazard Ranking System

HSWA - Hazardous and Solid Waste Amendments

IRIS - Integrated Risk Information System

IRM - Interim Remedial Measure

IRP - Installation Restoration Program

KCP - Key Chemical Parameters

LNAPL - Light Non-aqueous Phase Liquid

LWBZ - Lower Water Bearing Zone

MCL - Maximum Contaminant Level

MEDEP - Maine Department of Environmental Protection

MOM - Management of Migration

NCP - National Contingency Plan

NEPA - National Environmental Policy Act

NPL - National Priority List

O&M - Operation and Maintenance

OTA - Congress Office of Technology Assessment

OU - Operable Unit

PA - Preliminary Assessment

PAH - Polynuclear Aromatic Hydrocarbon

PCB - Polychlorinated Biphenyls

PI - Preliminary Investigation

POTW - Public Owned Treatment Works

ppb - Parts Per Billion

ppm - Parts Per Million

PRP - Potentially Responsible Party

QAPP - Quality Assurance Program Plan

RA - Remedial Action

RAAS - Remedial Action Assessment System

RACER - Remedial Action Cost Engineering and Requirements

RCRA - Resource Conservation and Recovery Act

RD - Remedial Design

RI - Remedial Investigation

RME - Reasonable Maximum Exposure

ROD - Record of Decision

RPM - Remedial Project Manager

SARA - Superfund Amendments and Reauthorization Act

SDWA - Safe Drinking Water Act, 1974, and as amended

SI - Site Inspection

SMOA - Superfund Memorandum of Agreement

SVE - Soil Vapor Extraction

SVOC - Semi Volatile Organic Compound

SWBZ - Shallow Water Bearing Zone

SWMU - Solid Waste Management Unit

TCE - Trichloroethene

TPH - Total Petroleum Hydrocarbons

TSCA - Toxic Substance Control Act

UHWS - Uncontrolled Hazardous Waste Site

UST - Underground Storage Tank

VOC - Volatile Organic Compound

DEFINITIONS

Action - Highest order of cleanup activity. Comprised of one or more alternatives.

Action Level - Maximum concentration of a key chemical parameter that will be allowed to remain after the remedial action is completed.

Alternatives - The means of achieving actions, as such they may be combined or serve individually. Alternatives are made up of one or more technologies.

Baseline studies - Is a one year minimum duration study that characterizes all static and dynamic physical and waste characteristics and natural-life aspects of the site.

CERCLIS - The official EPA computer listing of all known and reported uncontrolled hazardous waste sites, including those later found to be otherwise.

Containment - The hazardous waste cleanup philosophy of using techniques to encapsulate the wastes so they cannot leave the source area, while at the same time, are made inaccessible to humans and food-chain animals or wildlife.

Hazardous Ranking Score - A numerical method of quantifying the extent of contamination determined during the site investigation. If it is 28.50 or greater the site is eligible to be nominated by the Region administrator to the National Priority List.

Key Chemical Parameters - Chemical species selected during the Remedial Investigation, as representing the most toxic, most concentrated, and most mobile of contaminants at the site for which the Feasibility Study will select an appropriate remedy.

Operable Units - A distinct body of contamination that is sufficiently different from other such bodies as to require separate remediation.

Potentially Responsible Parties - Those companies, agencies, or individuals that may have been a generator or transporter of waste at a hazardous waste site or an owner or operator of the site. Usually contacted by the regional administrator at the completion of the site investigation. They have strict, joint and several liability for the site.

Records of Decision - The official selection of the means of remediating a site.

Remedial Action - Major concepts of cleanup, made up of alternatives and technologies. The ways and means by which the cleanup is accomplished.

Source Area - A distinct body of contamination that is the original source of migrated contamination.

Technologies - These are the components of alternatives. They are the most basic of the activities used to remediate sites.

APPENDIX B

AIR FORCE CLOSURE BASES/BASES SURVEYED

AIR FORCE CLOSURE BASES

1991

Pease Air Force Base, New Hampshire *

1992

Eaker Air Force Base, Louisanna *
England Air Force Base, Louisanna (Pretest)
George Air Force Base, California

1993

Bergstrom Air Force Base, Texas *
Carswell Air Force Base, Texas (Pretest)
Chanute Air Force Base, Illinois *
Homestead Air Force Base, Florida
Mather Air Force Base, California *
Myrtle Beach Air Force Base, South Carolina *
Williams Air Force Base, Arizona *
Wurtsmuth Air Force Base, Michigan *

1994

Grissom Air Force Base, Indiana *
Loring Air Force Base, Maine *
Lowry Air Force Base, Colorado
MacDill Air Force Base, Florida
Norton Air Force Base, California *
Richards-Gebaur Air Force Base, Missouri *
Rickenbacker Air National Guard Base, Ohio (Pretest)

1995

Castle Air Force Base, California *
Griffiss Air Force Base, New York *
K.I Sawyer Air Force Base, Michigan (Pretest)
Plattsburgh Air Force Base, New York *

1996

March Air Force Base, California *
Newark Air Force Base, Ohio *

1997

Gentile Air Force Station, Ohio (Pretest)

* Returned Survey

Air Force Bases Surveyed
(Does not include closure bases)

1. Arnold AFB, Tennessee *
2. Altus AFB, Oklahoma *
3. Andrews AFB, Maryland *
4. Barksdale AFB, Louisiana *
5. Beale AFB, California
6. Brooks AFB, Texas *
7. Cannon AFB, New Mexico *
8. Charleston AFB, South Carolina *
9. Columbus AFB, Mississippi
10. Davis-Monthan AFB, Arizona
11. Dover AFB, Delaware *
12. Dyess AFB, Texas
13. Edwards AFB, California *
14. Eglin AFB, Florida
15. Ellsworth AFB, South Dakota *
16. Fairchild AFB, Washington
17. Falcon AFB, Colorado *
18. F. E. Warren AFB, Wyoming *
19. Goodfellow AFB, Texas *
20. Grand Forks AFB, North Dakota *
21. Hanscom AFB, Massachusetts
22. Hill AFB, Utah *
23. Holloman AFB, New Mexico *
24. Keesler AFB, Mississippi
25. Kelly AFB, Texas *
26. Kirtland AFB, New Mexico *
27. Lackland AFB, Texas *
28. Langley AFB, Virginia *
29. Laughlin AFB, Texas
30. Little Rock AFB, Arkansas
31. Los Angeles AFB, California *
32. Luke AFB, Arizona *
33. Malmstrom AFB, Montana *
34. Maxwell AFB, Alabama *
35. McChord AFB, Washington *
36. McClellan AFB, California
37. McConnell AFB, Kansas *
38. McGuire AFB, New Jersey *
39. Minot AFB, North Dakota *
40. Moody AFB, Georgia *
41. Mountain Home AFB, Idaho *
42. Nellis AFB, Nevada *
43. Offutt AFB, Nebraska *
44. Patrick AFB, Florida *
45. Peterson AFB, Colorado *
46. Pope AFB, North Carolina *
47. Randoph AFB, Texas *
48. Reese AFB, Texas *
49. Robins AFB, Georgia
50. Scott AFB, Illinois *
51. Seymour Johnson AFB, North Carolina *

52. Shaw AFB, South Carolina *
53. Sheppard AFB, Texas *
54. Tinker AFB, Oklahoma *
55. Travis AFB, California *
56. Tyndall AFB, Florida *
57. Vance AFB, Oklahoma *
58. Vandenberg AFB, California *
59. Whiteman AFB, Missouri
60. Wright-Patterson AFB, Ohio *

* Returned Survey

APPENDIX C

SURVEY INSTRUMENT

Potential Cost Savings at Installation Restoration Program Sites

1. What is the Major Command of your base?

- ☐ Air Force Material Command
- ☐ Air Training and Education Command
- ☐ Other
- ☐ Air Mobility Command
- ☐ Air Combat Command
- ☐ Space Command

2. How many years have you been working with IRP, CERCLA or Hazardous waste site cleanups?

- ☐ 0-2 years
- ☐ 3-5 years
- ☐ 6-9 years
- ☐ 10+ years

3. What is the number of current IRP sites on your installation?

- ☐ 0-2 sites
- ☐ 3-5 sites
- ☐ 6-9 sites
- ☐ 10+ sites

4. How far along the cleanup process has an installation IRP site progressed?

- ☐ Preliminary Assessment (PA)
- ☐ Site Investigation (SI)
- ☐ Remedial Investigation (RI)
- ☐ Feasibility Study (FS)
- ☐ Record of Decision (ROD)
- ☐ Remedial Design (RD)
- ☐ Remedial Action (RA)
- ☐ Closure

5. Write the number of IRP sites on your installation that would fall into the following categories? (Include each site in only one category)

- ___ Fuel Storage facilities
- ___ Low level radioactive waste
- ___ Fire Training areas
- ___ Spills and Storage areas
- ___ Landfills
- ___ Disposal Pits
- ___ Waste Pits
- ___ Surface runoff

6. Rank the following measures for their potential to reduce cleanup costs at IRP sites. (1 = most potential to reduce costs)

- ___ Restricting future land use to present use
- ___ Use of containment verses treatment
- ___ National standardized cleanup levels
- ___ Realistic Risk Assessment process
- ___ Emerging innovative technologies

7. What savings to IRP cleanup costs do you feel can be achieved by restricting future use of the land to the current use?

- ☐ No Savings
- ☐ 1-5 percent
- ☐ 6-10 percent
- ☐ 11-15 percent
- ☐ 16-20 percent
- ☐ 21-25 percent
- ☐ 26-30 percent
- ☐ 31-40 percent
- ☐ 41-50 percent
- ☐ 51-75 percent
- ☐ Greater than 75 percent

8. What savings to IRP cleanup costs do you feel can be achieved by emphasizing containment verses cleanup?

- ☐ No Savings
- ☐ 1-5 percent
- ☐ 6-10 percent
- ☐ 11-15 percent
- ☐ 16-20 percent
- ☐ 21-25 percent
- ☐ 26-30 percent
- ☐ 31-40 percent
- ☐ 41-50 percent
- ☐ 51-75 percent
- ☐ Greater than 75 percent

9. What savings to IRP cleanup costs do you feel can be achieved by creating a national standardized cleanup standard?

- ☐ No Savings
- ☐ 1-5 percent
- ☐ 6-10 percent
- ☐ 11-15 percent
- ☐ 16-20 percent
- ☐ 21-25 percent
- ☐ 26-30 percent
- ☐ 31-40 percent
- ☐ 41-50 percent
- ☐ 51-75 percent
- ☐ Greater than 75 percent

10. What savings to IRP cleanup costs do you feel can be achieved by realistic risk assessments?

- ☐ No Savings
- ☐ 1-5 percent
- ☐ 6-10 percent
- ☐ 11-15 percent
- ☐ 16-20 percent
- ☐ 21-25 percent
- ☐ 26-30 percent
- ☐ 31-40 percent
- ☐ 41-50 percent
- ☐ 51-75 percent
- ☐ Greater than 75 percent

11. What savings to IRP cleanup costs do you feel can be achieved by emerging innovative technologies?

- ☐ No Savings
- ☐ 1-5 percent
- ☐ 6-10 percent
- ☐ 11-15 percent
- ☐ 16-20 percent
- ☐ 21-25 percent
- ☐ 26-30 percent
- ☐ 31-40 percent
- ☐ 41-50 percent
- ☐ 51-75 percent
- ☐ Greater than 75 percent

12. Additional Recommendations/Comments: ______________________________

____

____

(Include additional comments on separate sheet of paper)

APPENDIX D

SURVEY DATA AND SUMMARIES

SURVEY DATA

BASE #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
C1	3	3	4	7	1	0	4	15	10	0	0	0	2	1	3	4	5	6	7	4	2	1
C2	3	4	4	4	3	0	1	2	4	0	0	0						11	10	1	1	1
C4																						
C5	3	4	4	8	50	1	1	5	7	1	1	1	1	5	2	3	4	11	11	11	11	8
C7	3	4	4	3	19	0	2	4	4	1	0	1	4	5	3	2	1	1	1	5	8	10
C9	3	1	4	6	31	1	4	3	7	4	0	17						10	9	9	8	8
C10	3	4	4	7	1	0	4	25	5	0	0	0	3	4	2	1	5	5	11	5	10	4
C11	3	2	4	7	1	1	3	5	1	0	0	3	5	4	3	2	1	1	1	6	6	8
C12	3	2	4	4	17	0	2	19	9	0	1	0	4	5	2	3	1	4	1	5	4	10
C13	3	2	3	7	1	0	2	3	3	0	0	0	2	5	4	1	3	3	2	6	9	9
C14	3	3	4	7	1	1	1	39	10	0	0	1	5	3	4	2	1	3	5	2	9	9
C15																						
C16																						
C17	3	1	4	7	0	1	1	8	2	5	4	1	3	5	2	1	4	1	1	8	8	5
C18	3	3	3	7	4	0	1	2	0	0	0	0	2	3	5	1	4	3	3	1	7	2
C20	3	3	4	7	50	1	3	15	6	12	5	5	2	4	3	1	5	9	6	6	10	3
C21	3	2	4	3	8	0	3	20	7	4	5	2	1	3	5	2	4	9	5	3	8	4
C23	3	1	4	8	5	0	1	28	4	0	0	2	2	1	3	4	5	5	8	4	3	3
C24	3	3	4	8	21	0	1	3	9	0	0	0	4			1	3	7		9	5	5
C25	3	1	4	4	0	0	1	2	2	3	0	0	5	3	4	2	1	2	4	3	5	6
1	2	1	4	8	0	0	4	5	4	0	3	0	3	2	4	1	5	5	7	4	8	
2	4	2	4	7	10	1	3	5	3	0	1	0	1	3	4	2	5	11	9	8	9	5
3	5	3	4	3	2	0	2	2	1	2	0	2	1	3	4	2	5	10	5	8	10	5
4																						
5	1	1	4	8	0	0	1	2	6	2	0	0	5	2	4	1	3	1	9	1	10	6
6	5	1	4	3	6	0	4	7	6	2	0	4	1	4	2	3	4	6	2	6	6	
7	4	1	4	3	7	0	6	9	4	9	0	0	5	2	4	1	3	2	3	2	7	4
8																						
9																						
10	4	1	4	5	6	0	3	7	11		8	1	2	5	3	1	4	10	3	7	11	6
11																						
12	1	3	4	4	30	0	5	100	10	20	10	5	4	3	1	2	5	5	8	8	7	9
13																						
14	5	2	4	4	8	1	1	4	6	0	0	0	1	2	4	3	5	7	3	2	2	1
15																						
16	6	1	4	2	2	0	1	5	3	0	1	3	3	5	2	1	4	5	3	6	7	4
17	6	2	4	8	0	0	2	8	6	1	0	0	5	4	2	1	3	1	2	7	8	5
18	2	3	1		1	0	0	1	0	0	0	0	1	2				10	10			
19	4	2	2	7	1	0	1	1	2	1	0	0	4	5	3	1	2	4	1	7	9	8

20																						
21	1	3	4	8	46	1	3	24	5	4	2	3	2	3	5	1	4	8	3	1	10	6
22	5	1	4	7	18	2	1	16	11	3	2	6	2	4	3	1	5	6	3	4	9	2
23																						
24	1	4	4	4									5	3	2	1	4	3	5	5	9	5
25	1	3	4	3	8	9	2	8	10	2	5	2	3	1	5	2	4	3	5	2	4	4
26	2	1	4	7	10	6	2	3	1	2	2	1	1	2	4	3	5	10	9	6	6	6
27	5	1	4	8	13	0	1	8	11	0	0	2	3	1	4	1	2	3	11	1	11	10
28																						
29																						
30	1	2	4	2	0	0	0	20	6	8	0	1	5	4	1	2	3	2	3	7	7	5
31	2	2	4	3	1	0	2	0	5	5	0	4	1	4	5	2	3	11	5	2	10	8
32	6	2	4	8	7	1	1	4	3	0	0	2	5	4	3	1	2	1	2	6	9	9
33	2	2	4	8	16	0	2	15	7	1	0	2	2	3	5	1	4	4	2	1	11	2
34	4	3	4	7	3	2	7	15	22	6	5	5	1	4	5	2	3	10	6	2	9	7
35																						
36	4	3	4	8	1	1	5	5	2	1	0	0	1	3	4	2	5	11	3		11	6
37	4	2	4	7	1	1	3	2	6	3	1	3	4	5	3	1	2	5	3	6	9	8
38	5	1	2	6	1	0	1	0	0	1	0	0	2	3	1	5	4	5	9	5	1	6
39	5	1	4	4									1	3	5	2	4					
40	5	2	4	5	3	1	6	12	2	6	0	2	1	3	4	2	5	11	9	8	10	7
41	5	4	4	8	3	4	3	2	12	5	6	2	2	5	3	1	4	10	5	6	11	1
42	5	2	4	6	4	1	3	5	5	0	0	1	2	5	3	1	4	8	3	5	10	3
43	6	2	4	4	24	0	4	1	6	40	0	0	4	5	3	1	2	8	5	8	11	10
44	6	1	4	5	0	0	3	9	4	4	1	0	5	1	3	4	2	3	11	9	6	9
45	5	2	3	3	2	0	1	3	2	1	0	0	3	4	5	1	2	6	5	4	8	7
46	2	1	4	5	9	1	5	2	3	0	1	0	2	5	3	1	4	6	1	3	9	8
47	2	1	4	3	4	0	5	0	14	1	2	0	3	2	5	1	4	3	7	2	9	4
48																						
49			4	2	4	3	2	1	3	2	1	0	0	0	4	5	2	1	3		10	9
50	5	2	4	8									5	4	2	1	3	1	1	6	7	5
51	5	1	4	7	9	0	3	6	3	2	0	2	3	4	2	1	5	8	6	7	9	3
52	2	1	4	8	6	2	3	0	3	1	2	0	1		2		3			9	10	10
53	1	4	4	7	7	5	3	7	6	0	3	5	4	2	1	3	5	8	9	10	8	7
54	4	4	4	3	5	2	4	6	3	0	0	1	2	5	4	1	3	10	3	3	3	3
55	2	1	4	4	6	1	3	4	13	5	0	0	1	4	5	2	3	8	5	4	7	6
56	2	4	4	4			2						4	2	3	1	5	3	10	8	11	3
57	6	1	4	3		0	1						4	3		1	2	3			6	4
58																						
59	1	3	4	7	6	2	5	11	14	5	0	0	1	5	2	3	4	6	2	5	3	2
60	1	3	4	7			2	9	2	5	2	4	4	3	2	1	5	3	6	7	9	4

Survey Variable Descriptions

1. Command = Major Command of base
   1 - Air Force Material Command
   2 - Air Education and Training Command
   3 - Other (Air Force Base Conversion Agency)
   4 - Air Mobility Command
   5 - Air Combat Command
   6 - Space Command

2. Years = Number of years working with IRP
   1 - 0-2 years
   2 - 3-5 years
   3 - 6-9 years
   4 - 10+ years

3. #_Sites = Number of IRP sites at base
   1 - 0-2 sites
   2 - 3-5 sites
   3 - 6-9 sites
   4 - 10+ sites

4. Progress = How far along the cleanup process an IRP site has progressed

   1 - Preliminary Assessment
   2 - Site Investigation
   3 - Remedial Investigation
   4 - Feasibility Study
   5 - Record of Decision
   6 - Remedial Design
   7 - Remedial Action
   8 - Closure

5. Fuel = Number of IRP sites that are fuel storage facilities

6. Radioactive = Number of IRP sites that are low-level radioactive waste sites

7. Fire = Number of IRP sites that are fire training areas

8. Spills = Number of IRP sites that are spills and storage areas

9. Landfill = Number of IRP sites that are landfills

10. Disposal_Pits = Number of IRP sites that are disposal pits

11. Waste_Pits = Number of IRP sites that are waste pits

12. Runoff = Number of IRP sites that are surface runoff

13. Land = Rank of land-use restriction as a cost savings measure

14. Contain = Rank of increased use of containment as a cost savings measure

15. Standard = Rank of standardized cleanup levels as a cost savings measure

16. Risk = Rank of realistic risk assessments as a cost savings measure

17. Technology = Rank of emerging innovative technologies as a cost savings measure

18. Land_sav = Amount of savings possible with land-use restriction

    1 - No savings
    2 - 1-5 percent
    3 - 6-10 percent
    4 - 11-15 percent
    5 - 16-20 percent
    6 - 21-25 percent
    7 - 26-30 percent
    8 - 31-40 percent
    9 - 41-50 percent
    10 - 51-75 percent
    11 - Greater than 75 percent

19. Contain_sav = Amount of savings possible with increased use of containment

    1 - No savings
    2 - 1-5 percent
    3 - 6-10 percent
    4 - 11-15 percent
    5 - 16-20 percent
    6 - 21-25 percent
    7 - 26-30 percent
    8 - 31-40 percent
    9 - 41-50 percent
    10 - 51-75 percent
    11 - Greater than 75 percent

20. Standard_sav = Amount of savings possible with standardized cleanup standards

1 - No savings
2 - 1-5 percent
3 - 6-10 percent
4 - 11-15 percent
5 - 16-20 percent
6 - 21-25 percent
7 - 26-30 percent
8 - 31-40 percent
9 - 41-50 percent
10 - 51-75 percent
11 - Greater than 75 percent

21. Risk_sav = Amount of savings possible with a realistic risk assessment process

1 - No savings
2 - 1-5 percent
3 - 6-10 percent
4 - 11-15 percent
5 - 16-20 percent
6 - 21-25 percent
7 - 26-30 percent
8 - 31-40 percent
9 - 41-50 percent
10 - 51-75 percent
11 - Greater than 75 percent

22. Technology_sav = Amount of savings possible with emerging innovative technologies

1 - No savings
2 - 1-5 percent
3 - 6-10 percent
4 - 11-15 percent
5 - 16-20 percent
6 - 21-25 percent
7 - 26-30 percent
8 - 31-40 percent
9 - 41-50 percent
10 - 51-75 percent
11 - Greater than 75 percent

Survey Response to the Amount of Savings Possible
From Land-use Restriction Broken Down by Experience

	1	2	3	4	5	6	7	8	9	10	11
0-2 years	2	2	4	0	4	3	0	2	0	3	0
3-5 years	4	1	1	3	1	1	1	2	1	0	3
6-9 years	0	0	4	0	1	2	1	1	1	3	1
10+ years	1	0	2	0	1	0	0	1	0	2	2

Survey Response to the Amount of Savings Possible
From Land-use Restriction Broken Down by Number of
Sites at the Installation

	1	2	3	4	5	6	7	8	9	10	11
0-2	0	0	0	0	0	0	0	0	0	1	0
3-5	0	0	0	1	1	0	0	0	0	0	0
6-9	0	0	2	0	0	1	0	0	0	0	0
10+	7	3	9	2	6	5	2	6	2	7	6

Survey Response to the Amount of Savings Possible From Land-use Restriction Broken Down by Air Force Major Command

	1	2	3	4	5	6	7	8	9	10	11
Air Force Material Command	1	1	3	0	1	1	0	2	0	0	0
Air Education & Training Command	0	0	2	1	1	1	0	1	0	2	1
Air Force Base Conversion Agency	3	1	3	1	2	1	1	0	2	1	2
Air Mobility Command	0	1	0	1	1	0	0	0	0	3	2
Air Combat Command	1	0	1	0	1	3	1	2	0	2	1
Space Command	2	0	2	0	1	0	0	1	0	0	0

Survey Response to the Amount of Savings Possible From Land-use Restriction Broken Down by the Progress of Sites on the Installation

	1	2	3	4	5	6	7	8	9	10	11
Preliminary Assessment	0	0	0	0	0	0	0	0	0	0	0
Site Investigation	0	1	0	0	1	0	0	0	0	0	0
Remedial Investigation	1	1	3	0	0	2	0	0	1	2	1
Feasibility Study	0	1	2	1	1	0	1	2	0	0	1
Record of Decision	0	0	1	0	0	1	0	0	0	1	1
Remedial Design	0	0	0	0	1	0	0	1	0	1	0
Remedial Action	2	0	4	1	2	3	0	2	1	2	1
Closure	4	0	1	1	2	0	1	1	0	1	2

Ranking of Land-use Restriction as a Cost Savings Measure by Respondents broken down by Experience

	1st	2nd	3rd	4th	5th
0-2 years	5	5	6	1	4
3-5 years	5	3	1	5	5
6-9 years	5	4	1	3	1
10+ years	1	2	1	3	1

Ranking of Land-use Restriction as a Cost Savings Measure by Respondents broken down by the number of sites at the installation

	1st	2nd	3rd	4th	5th
0-2	1	0	0	0	0
3-5	0	1	0	1	0
6-9	0	2	1	0	0
10+	15	11	8	11	11

Ranking of Land-use Restrictions as a Cost Savings Measure by Respondents broken down by Air Force Major Command

	1st	2nd	3rd	4th	5th
Air Force Material Command	1	1	1	3	3
Air Education & Training Command	5	2	2	1	0
Air Force Base Conversion Agency	2	5	2	3	3
Air Mobility Command	3	2	0	3	1
Air Combat Command	5	4	3	0	1
Space Command	0	0	1	2	3

Ranking of Land-use Restriction as a Cost Savings Measure by Respondents broken down by Progress of Sites at the Installation

	1st	2nd	3rd	4th	5th
Preliminary Assessment	0	0	0	0	0
Site Investigation	0	0	1	0	1
Remedial Investigation	4	1	3	3	1
Feasiblity Study	3	0	0	4	2
Record of Decision	1	2	0	0	1
Remedial Design	0	2	0	0	0
Remedial Action	4	5	3	4	2
Closure	3	4	2	1	4

APPENDIX E

SURVEY COMMENTS

SURVEY COMMENTS

- Appears your research begs the question "If a base is subject to RCRA/HSWA regulation by the state (or EPA) does it really have any legal obligation to have a duplicate IRP program (waste of taxpayers $$'s)." At an active AFB the answer is obviously "yes" (to satisfy Command, Air Staff and DOD requirements), but at a closing base, the answer is obviouly "No"!!

- It is very difficult to get regulators to buy in to any of the five areas (potential cost reduction methods). New technologies are the easiest to sell to regulators.

- Bases with existing landfills should consider consolidating soils into landfills prior to closing them with final cover.

- It is probable that for a significant portion of IRP sites a combination of the measures suggested would work best to reduce costs. (Also disposal pit and waste pit should be defined for this form, if used again.)

- This is Air Force property, DLA has controlled the use of it for the past 32 years. DLA is funding the BRAC cleanup.

- Eliminate the CY 2000 AF goal of having all sites finished. Eliminate the goal of 60% of DERA funds going to remediation. Let the bases run their own programs, i.e. eliminate MAJCOM second guessing.

- Changing the requirement for Applicable or Relevant and Appropriate Requirements (ARARs). When a regulation is not applicable it should not be applied. Case in point: Many sites have contamination in groundwater that is not useable as a source of drinking water either because its quality is otherwise poor (e.g. high TDS) or there is not enough of it to make it a viable source to pump. Both of these conditions exist together at this AFB, yet we are required by the EPA and State regulators to cleanup to a drinking water standard. The reality is that if (big if) this water is ever used as a source of drinking water it will require treatment anyway. Elimination of this requirement will save more money than any of the alternatives listed.

- National cleanup standard would hurt some IRP sites and help others (costwise). Containment is not fixing the problem yet you are still spending $. We have technologies that will work now - new ones have yet to prove they are that much better and they will still cost $, after all - contractors do want to make $.

- Major, 40-60%, cost reductions could be achieved by streamlining cleanup process, i.e. the NCP. You should look at fixing the system, not just the best way to do final cleanup!

- Unrealistic cleanup standards, coupled with unrealistic processes for evaluating risk are the two most significant factors that cause the ridiculously high remediation costs.

- Contractor (consultant) and regulator must be challenged anytime they suggest more investigation/cleanup.

- Throughly investigating areas of concern before they become "sites" may help streamline the process and reduce costs. If you can show little or no risk at the SI stage, even if contamination is above standards, areas of concern can be closed before they reach the costly RI/FS stage.

- Realistic Risk Management assessments and long term restricted land use will be the most effective at this AFB to save further cleanup costs.

- The Air Force cannot produce these savings unilaterally, especially at NPL bases with FFAs. The Air Force **MUST** work with EPA and state regulators to develop an assortment of tools to reduce costs. With the EPA, this means working with the Regions, not just the national headquarters, because of their autonomy. As far as the states go, they are under absolutely **NO** obligation to follow any laws or standards less stringent than their own. It is also necessary to recognize that at this time it is probably easier to save money on investigations rather than Remedial Actions, assuming, of course, that we are actually talking about doing an action. RI/FS dollars can be saved by using the EPA Superfund Accelerated Cleanup Model (SACM) initiative and the resultant emerging Presumptive Remedies such as landfill containment. These avenues allow Remedial Actions to begin quicker by identifying the minimum contamination necessary to trigger an action thus necessitating fewer monitor wells, less chemical analysis and a streamlined Risk Assessment approach to complete the RI/FS. Conversely, however, if we intend to persue No Action, No Further Action, Natural Attenuation, Intrinsic Bioremediation or similar non-actions as our planned cleanups then we must be prepared to perform exhaustive (and expensive) data gathering and evaluation. Unless or until the public (read environmental activists) can be convinced that parts per billion or lower contamination levels and one in a million risks are less serious than currently perceived, Mega-doses of dollars for investigations and risk assessments will continue to be required.

Actual savings on cleanups - Remedial Actions - can probably be achieved by a mix of national standards, realistic risk assessment and innovative technology. The savings achievable is probably limited by one of the areas such that a site (base) under a national standard, with a realistic Risk Assessment and using (Real) innovative technology might save say 40%, not 70%, for example.

One major concern I have relating to this topic is, how many different names can we give to not doing actual cleanup? It seems to me (and many regulators, too, I'm sure) that Intrinsic Bioremediation and Natural Attenuation are both simply fancy names for not taking any **REAL** cleanup action. What is being done about finding innovative technologies that actively and aggressively cleanup contamination?

- Establish an MOU w/USEPA to renegotiate all DOD FFA's. New FFA to rely on maximum use of removal actions with a single RI/FS to validate effectiveness of final cleanup.

APPENDIX F

ROD SUMMARIES

ROD SUMMARIES

This Appendix provides a brief synopsis of information contained in the ROD for each site analyzed. The synopsis gives a brief site characterization, risk characterization, and description of the selected remedy and its associated cost.

Castle Air Force Base, Interim Operable Unit 1

Castle AFB is located in Merced County, California approximately six miles northwest of the City of Merced. The Base covers an area of 2,777 acres. (57:2-1)

Fuels (JP-4), solvents (TCE) and chemicals have been handled at the Base since the 1940s. Municipal and chemical wastes have also been generated as a results of maintenance operation, fuel management, fire training, and other Base activities. (57:2-4)

Land-use within a two-mile radius is primarily agricultural. Several small dairies and a large chicken farm are located to the east. Open pastures are located to the north and east. Residential areas are located primarily west of the Base and include Military Base housing, and a variety of civilian trailer parks, recently constructed residential suburban housing and rural farm residences.

There are major surface water bodies within five miles of the Base. Domestic and agricultural water are supplied to the region by both groundwater wells and the canals of the California Central Valley irrigation projects. (57:2-1)

In 1980, during routine sampling trace levels of TCE were detected in the four base water production wells. In March 1984, the California Regional Water Quality Control Board ordered the Base to provide users of the Base water supply and impacted off-base wells with potable water. (57:2-4)

Interim Operable Unit 1 is to address the remediation of the contaminated groundwater by eliminating or reducing the risks posed by the site. The final remedy will be selected in a later ROD. (57:1-2)

The lateral area delineated by the Main TCE Plume exceeds 212 acres. The principal risk to the public health is the portion of the plume to the south and southwest of the Base, which has the potential to impact off-base residential water wells. Delays in remediating the plume could potentially affect additional wells and a greater area. (57:3-1)

This sense of urgency allowed the ROD to proceed without the risks being fully characterized, since the Maximum Contaminant Level of 5 ppb was exceeded in the plume. (57:5-1)

The selected interim remedy includes:

- Pumping the groundwater from a series of shallow aquifer extraction wells to maintain hydraulic control of the plume and begin reducing residual TCE concentrations.

- Surface treating the extracted groundwater by air stripping.

- Reinjecting the treated groundwater back to the shallow aquifer to assist in maintaining hydraulic control and to avoid depletion of the aquifer.

- Applying natural biological enhancement to accelerate the degradation of hazardous constituents in the saturated zone.

- Abating the air stripper emissions with granular activated carbon. (57:1-2)

The estimated cost of the interim remedy is $42,354,608.

Castle Air Force Base, Operable Unit 2

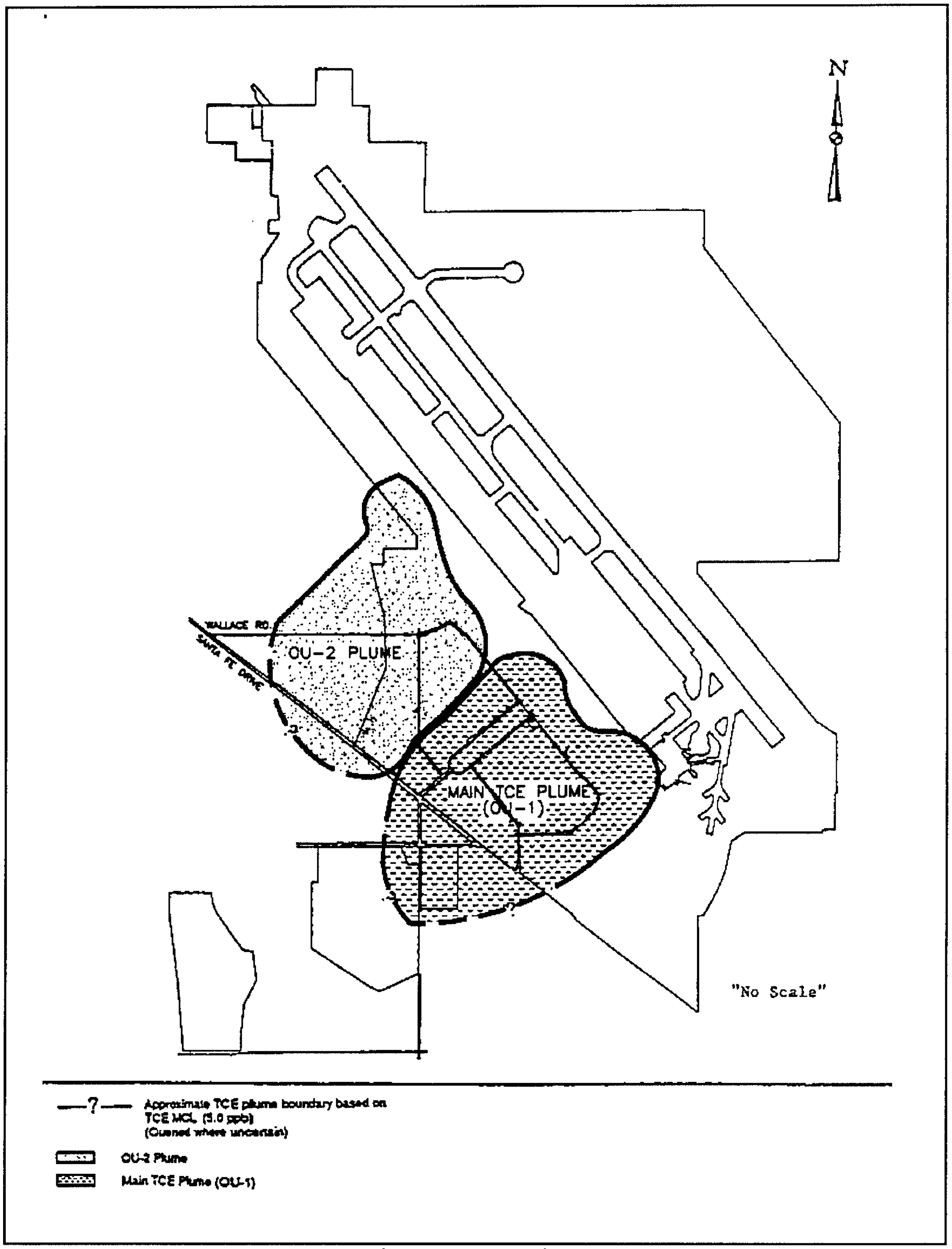
Castle AFB is located in Merced County, California approximately six miles northwest of the City of Merced. The Base covers an area of 2,777 acres. (57:2-1)

Fuels (JP-4), solvents (TCE) and chemicals have been handled at the Base since the 1940s. Municipal and chemical wastes have also been generated as a results of maintenance operation, fuel management, fire training, and other Base activities. (57:2-4)

Land-use within a two-mile radius is primarily agricultural. Several small dairies and a large chicken farm are located to the east. Open pastures are located to the north and east. Residential areas are located primarily west of the Base and include Base housing, trailer parks, recently constructed residential suburban housing and rural farm residences.

There are major surface water bodies within five miles of the Base. Domestic and agricultural water are supplied to the region by both groundwater wells and the canals of the California Central Valley irrigation projects. (57:2-1)

OU2 is defined as the contaminated groundwater under the area on Base referred to as Discharge Area No. 4 and the contiguous area off-base where contamination has migrated.



Castle AFB, Operable Unit 2 Location Map (58:6)

The system will be designed to remediate degraded groundwater that is not laterally covered by the interim OU1 system. (58:4)

TCE is the primary chemical of concern at OU2, however other VOCs have been detected in the groundwater (58:22).

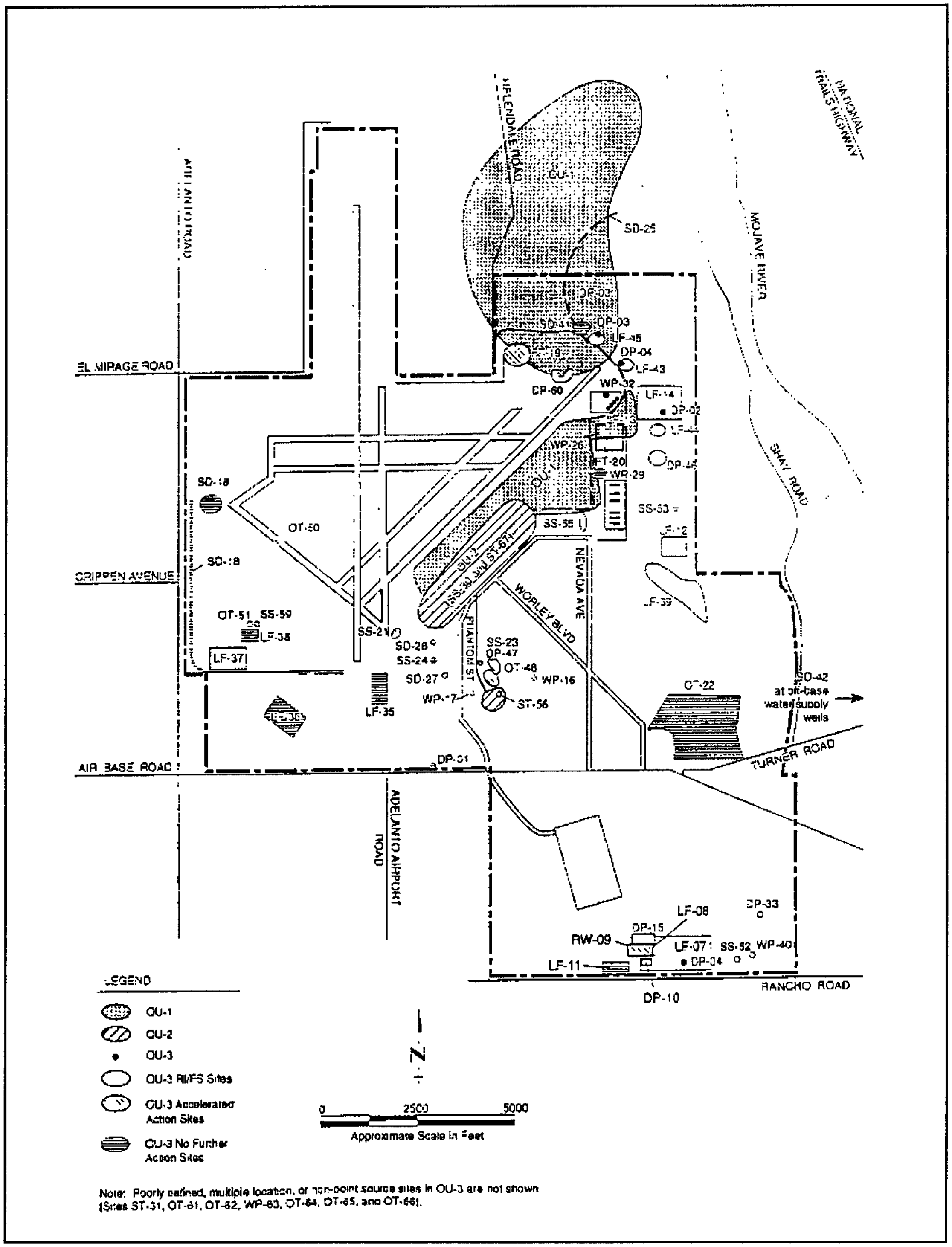
Because residential development is located on part of OU2 the Risk Assessment evaluated the future risk of residential exposure (58:22). The Risk Assessment concluded that the excess lifetime cancer risk, assuming residential use of contaminated groundwater and spray irrigation for all chemicals of concern is 1.99×10^{-2} for adults and 1.83×10^{-2} for children. This exceeds the EPA acceptable range of 10^{-4} to 10^{-6}. Groundwater contamination was determined to pose an unacceptable risk to human health as a drinking water source. (58:23)

The selected remedy consists of groundwater extraction and treatment with a packed tower air stripper and carbon treatment of air stripper off-gases, reinjection and groundwater monitoring (58:2).

The selected remedy will last 16 years and will cost an estimated $3,776,000.

George Air Force Base, Operable Unit 1

George AFB is located in the Victor Valley in the western Mojave Desert, in the area of Victorville, California and adjacent to the City of Adelanto. It is approximately 70 miles northeast of Los Angeles, 35 miles north of San Bernardino and 31 miles south of Barstow. (59:2-1)



George AFB, Operable Unit 1 Location Map (59:2-1)

Victor Valley is comprised of alluvial fan deposits derived from the surrounding mountains, river deposits associated with the Mojave River system, and lacustrine deposits from former Pleistocene-aged lakes. The Mojave River flows along the east side of the base in a northwesterly direction. The alluvial sediments consist of potentially water-bearing sands and gravels and low permeability silts and clays. The depth to bedrock is at least 1,350 feet. Data has identified two distinct water-bearing zones; a shallow "Upper Aquifer" and a deeper "Regional Aquifer", separated by a "Middle Clay/Silt Aquitard". Groundwater flow in the Mojave River and the Regional Aquifer are parallel. (59:2-6)

OU1 consists of a TCE plume beneath the northern part of the base including the Northeast Disposal Area and former Sewage Treatment Plant Percolation Ponds. Several sites within the Northeast Disposal Area were identified as potential sources of the TCE contamination in the groundwater. Soil contamination is being addressed in another operable unit.

The result of groundwater modeling indicated the plume would move northeasterly and discharge into the Mojave River in about 15 years, with a maximum estimated concentration of 10 ppb. The model predicted that the existing Victor Valley Water Reclamation Authority wells would be slightly impacted by the plume, although concentrations were predicted to remain below 5 ppb. These wells are not used for potable water; therefore, the projected impact is not anticipated to be

significant. No other water supply wells are known to exist in the path of the plume. (59:2-19)

The Base has seven and City of Adelanto has three municipal water supply wells near the Mojave River below the base golf course and beyond the eastern base boundary.

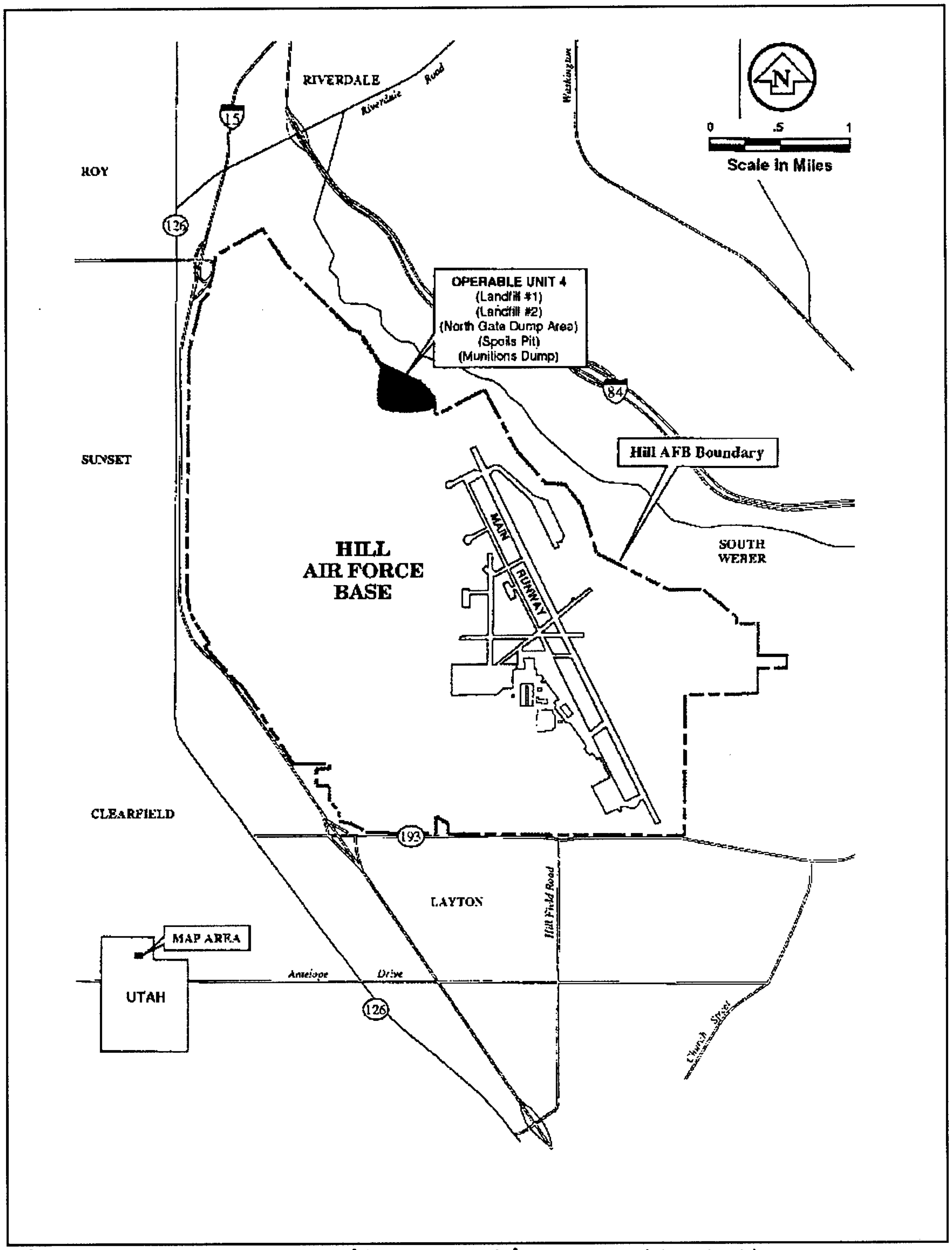
A Risk Assessment associated with the TCE was performed. There is no current exposure pathway to create a risk. The risk to a future resident using the groundwater beneath the Northeast Disposal Area was at $3X10^{-5}$ for the combination of water ingestion, dermal contact, and inhalation of volatiles from the groundwater. This risk level is within the 10^{-4} to 10^{-6} range established by the EPA, but above the $1X10^{-6}$ level set by the State of California. (59:2-21)

The selected remedy consists of an estimated 19 groundwater extraction wells installed in the Upper and Regional Aquifers, followed by treatment of the extracted groundwater using two air stripping towers in series, and recharge of treated groundwater at the former Sewage Treatment Plant Percolation Ponds.

The estimated cost is approximately $9,083,267.

Hill Air Force Base, Operable Unit 4

Hill AFB is located in northern Utah, about 25 miles north of Salt Lake City and five miles south of Ogden. Hill AFB covers about 6,700 acres and is located on the Weber Delta, a terrace approximately 300 feet above the surrounding valley floors in Weber and Davis counties. The site is near the northern boundary of the base and consists of the North



Hill AFB, Operable Unit 4 Location Map (60:1-1)

Gate Dump Area, the Spoils Pit, the Munitions Dump, and Landfills 1 and 2. (60:1-1)

The site is on a steep, terraced, north-facing escarpment of the Weber Delta. The stratigraphy is heterogeneous, with groundwater flowing mainly along thin sand layers found between low permeability clayey materials. The site overlies three aquifers. The shallow aquifer consists of 200 feet of relatively low-yielding materials and lies within about 30 feet of ground surface. The Sunset and Delta Aquifers are approximately 300 and 600 feet below the landfills respectively. The Sunset and Delta Aquifers are used by Hill AFB and surrounding communities as domestic water supplies. Groundwater flow in the shallow aquifer is to the north, discharging to off-base seeps along the north escarpment or to the floodplain deposits of the Weber River. (60:1-1)

The Weber River and the Davis-Weber Canal are the primary surface water bodies near the site. The Weber River is located over 3,000 feet north of the site and approximately 300 feet below the terrace where Landfills 1 and 2 are located. The Davis-Weber Canal is a privately owned irrigation canal used each year from April to October and is approximately 600 feet north and 100 feet below the landfills. (60:1-1)

The areas adjacent to the site to the north and northeast include the communities of Washington Terrace, Riverdale, and South Weber. These are moderately developed residential areas separated by large tracts of agricultural land. (60:1-1)

Landfill 1 received solid wastes from 1955 to 1967. The wastes were burned daily. There is no record of hazardous wastes being disposed of at the Landfill. Landfill 2 received solid wastes from 1963 to 1965. The wastes were burned periodically. There is no record of hazardous wastes being disposed of at the Landfill. The Spoils Pit received construction debris and yard waste from the Base from 1971 to 1987. There is no record of hazardous wastes being disposed of at the Spoils Pit. The Munitions Dump served as an aboveground munitions storage area during World War II. Several drums of waste solvent have been reported as dumped from trucks in the North Dump Area. No drums have yet been found in the area. (60:2-1)

Investigations have found Landfill 2, Spoils Pit, Munitions Dump and North Gate Dump Area are not sources of contaminates at the site. Landfill 1 has been found as a source of TCE contamination. (60:2-1)

TCE is considered the principal contaminant at the site since it is the only VOC consistently detected in groundwater and seeps at concentrations exceeding its maximum contaminant level. (60:3-1)

The area of contaminated groundwater is approximately 69 acres, located in the upper 25 feet of the shallow aquifer. Primary groundwater movement is lateral and contaminants have not migrated into the deeper aquifers. (60:3-1)

The Risk Assessment used both a current and future exposure scenario in determining the risks. The scenario for

future domestic use assumes that the future land-use at Hill AFB will include houses in the vicinity of the site, the houses will have domestic wells that use the shallow aquifer, and the groundwater extracted will have concentrations equal to the most contaminated portion of the aquifer. (60:3-6)

There is no risk associated with current land-use scenarios that exceed 10^{-6} or Hazard Index of 1.0. The greatest risk is $2X10^{-7}$ for inhalation of outdoor air by residents. (60:3-9)

For future residential domestic use of the shallow groundwater the Hazard Index was established at 6 with an excess carcinogenic risk estimated at $1X10^{-3}$. Future residential risks for use of the groundwater in the Sunset Aquifer was $1X10^{-8}$ and a Hazard Index of $5X10^{-4}$. (60:3-9)

The selected remedy includes:

- Extracting contaminated groundwater and treating by air stripping, and discharging the treated groundwater to the local publicly-owned treatment works (POTW);

- Collecting and treating surface water with carbon adsorption;

- Capping the contents of Landfill 1 and treating soil with soil vapor extraction;

- Semi-annual air monitoring in the basements of residences overlying contaminated groundwater, and;

- Water rights and well drilling restrictions to prevent exposure to contaminated groundwater.

The total estimated cost of the selected remedy is $9,583,742.

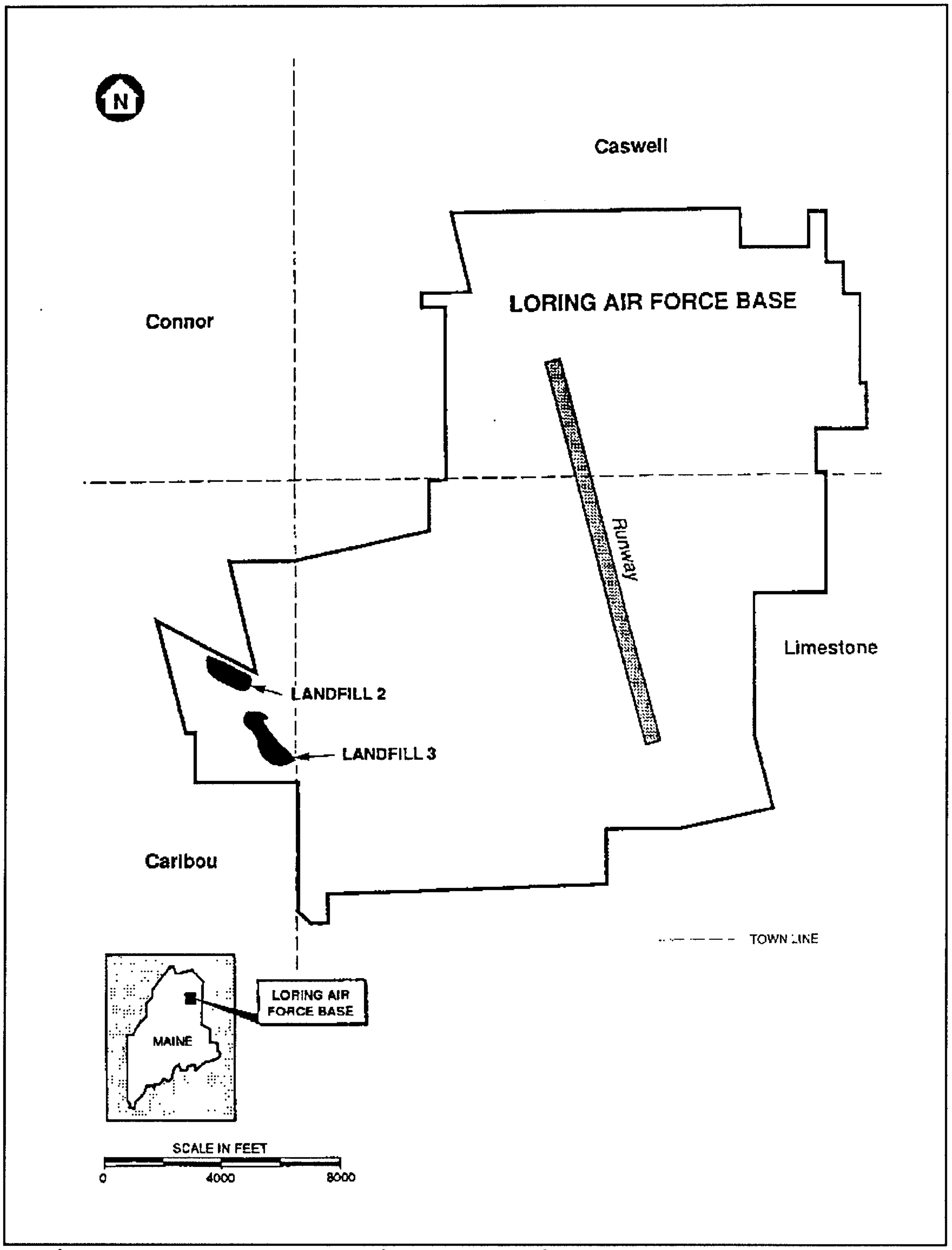
Loring Air Force Base, Operable Unit 2

Loring AFB is located in northeastern Maine. It is bordered on the south and east by the Town of Limestone, on the north by the Towns of Caswell and Connor, and on the west by the City of Caribou. The population's of Caswell, Connor and Limestone are 408, 468, and 2,093 respectively. The base is approximately 3 miles west of the United States/Canadian border and covers approximately 9,000 acres. (61:1-1)

Loring AFB has been engaged in a number of operations which require the use, handling, storage, or disposal of hazardous materials and substances. In the past, these materials entered the environment through accidental spills, leaks in supply piping, landfilling operations, burning of liquid wastes during fire training exercises, and the cumulative effects of operations conducted at the base's flightline and industrial areas. (61:1-1)

Located approximately one mile from the west gate is Landfill 2. It received waste from base activities from 1956 to 1974. The landfill covers approximately 9 acres, and was covered in 1974 with one foot of clean soil. Decomposition settling has formed two separate intermittently wet areas on the surface of the landfill. It is also possible that groundwater contacts the landfilled wastes during part of the year.
(61:1-3)

Located approximately one-half mile from the west gate is Landfill 3. The landfill received waste from base activities



Loring AFB, Operable Unit 2 Location Map (61:1-2)

from 1974 to 1991. Located northeast of the landfill is a Coal Ash Pile. The ash pile and landfill are separated by a dirt access road. Prior to use as a landfill, the site was mined extensively for gravel and quarrying operations continue today in the northeastern portion of the site. The landfill covers approximately 17 acres, and has been covered with 6 inches of native soils. Several small wet areas have been identified on the periphery of the landfill. A wetland of approximately five acres is located west of the landfill at a higher elevation. (61:1-3)

The operable unit comprises the source control and soil remediation action for Landfill 2 and Landfill 3 (61:vii).

Landfill 2 was used to dispose of domestic waste, construction debris, flightline wastes such as fuels, oil, solvents, hydraulic fluids, and paint, and sewage sludge. There is no record of waste segregation within the Landfill. Oil-filled switches, containing an estimated quantity of more than 3,000 gallons of oil and possibly containing polychlorinated biphenyls (PCBs) were reportedly disposed of at the site. Wastes were typically burned and buried. (61:2-1)

Hazardous wastes are not known to have been placed in Landfill 3. However, small quantities of waste oil, fuel, solvents, paints, thinners, hydraulic fluids may have been buried in the Landfill prior to the enactment of RCRA. (61:2-1)

Potential migration pathways identified are contaminants from the landfill materials migrating into the bedrock aquifer via surface water percolation, leachate seepage to surface water on top of the landfill material, volatilization, and migration by wind and fugitive dust contaminated soil particles. Minimal overland transport of contaminants to surface water bodies away from the landfills is anticipated. Surface water, sediment, and groundwater samples indicate the VOC and organics in the landfills have migrated to surface water on or adjacent to the landfills. (61:5-19)

Chemicals of potential concern selected for evaluation in the Risk Assessment included 16 for Landfill 2 surface soil, 17 for Landfill 2 surface water, 21 for Landfill 2 sediment, 3 for Landfill 2 groundwater, 12 for Landfill 3 surface soil, 6 for Landfill 3 surface water, 21 for Landfill 3 sediment, and 6 for Landfill 3 groundwater. (61:6-1)

In the Risk Assessment a current land-use scenario, current trespassing scenario and a future residential scenario were examined (1:6-14). While EPA uses a carcinogenic risk range of 10^{-4} to 10^{-6}, Maine Department of Environmental Protection (MEDEP) uses a value of $1X10^{-5}$ (61:6-21). At Landfill 2, both current and future cancer risk estimates exceeded the MEDEP cancer risk guidance value (61:6-22).

For Landfill 3, the total cancer risk for a child trespassing across both medias and pathways using the maximum exposure values equal $1X10^{-5}$, which equals the MEDEP cancer risk guidance value and is within the EPA cancer risk range

(61:6-24). The risk drops to $4X10^{-6}$ using average exposure values (61:6-25).

The adult future residential risk for cancer also equal $1X10^{-5}$. However the noncarcinogenic risk Hazard Index equals 19, well above the standard of 1.0 (61:6-25).

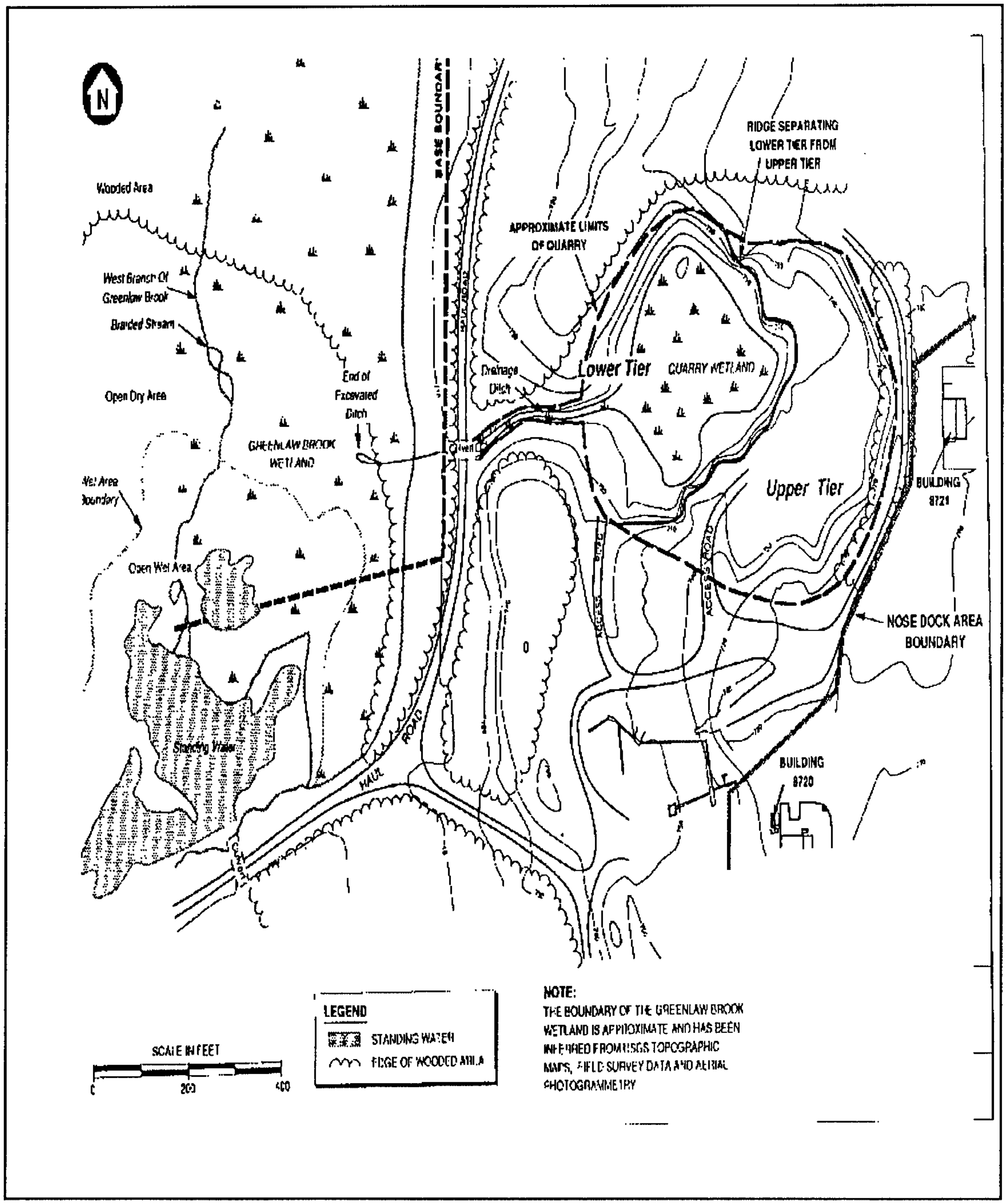
The selected remedy is containment using a cover system for both Landfill 2 and 3. The cover system includes gas assessment and control, and assessment of adjacent wetlands. Deed restrictions will also be placed on land in the vicinity of the landfills. (61:viii)

The selected remedy is estimated to cost approximately $25,412,400.

Loring Air Force Base, Operable Unit 7

Loring AFB is located in northeastern Maine. It is bordered on the south and east by the Town of Limestone, on the north by the Towns of Caswell and Connor, and on the west by the City of Caribou. The population's of Caswell, Connor and Limestone are 408, 468, and 2,093 respectively. The base is approximately 3 miles west of the United States/Canadian border and covers approximately 9,000 acres. (61:1-1)

Loring AFB has been engaged in a number of operations which require the use, handling, storage, or disposal of hazardous materials and substances. In the past, these materials entered the environment through accidental spills, leaks in supply piping, landfilling operations, burning of liquid wastes during fire training exercises, and the cumulative effects of operations conducted at the base's



Loring AFB, Operable Unit 7 Location Map (62:1-4)

flightline and industrial areas. (61:1-1)

Approximately 800 feet east of the western base boundary is a Quarry Site. The site encompasses approximately seven acres and served as a source of limestone rock for Loring AFB from 1947 to 1985 (62:2-1). The nearest residence is approximately two miles west of the Quarry and the land adjacent to the Quarry is the Greenlaw Brook wetland (62:1-1). The Operable Unit comprises the Quarry Site soils and sediments (62:1-1).

The Quarry consists of two levels, the upper and lower tiers. The circular shaped lower tier of the Quarry, approximately two acres in size, is flooded seasonally and drains through an excavated ditch into the Greenlaw Brook wetland. Approximately 95 percent of the lower tier consists of an emergent marsh wetland area. (62:1-2)

The upper tier is approximately 2.5 acres, crescent-shaped and bordered on the north and east by rock and construction debris. To the west, the upper tier drops approximately 30 feet to the lower tier. (62:1-2)

Historically, waste materials from construction projects, industrial and maintenance shops, and other base activities were stored at the Quarry Site. Approximately 100 55-gallon drums were observed in the upper tier in 1983. Overall there have been miscellaneous reports of drums at the site throughout the 1980s. Reports consistently note their presence at the eastern and northern portions of the upper tier. (62:2-1)

The Risk Assessment identified, 28 contaminants of potential concern for the upper tier soils, 22 for the lower tier soils, 31 for sediment from the Greenlaw Brook wetland and drainage ditch, and eight for the surface water from the Greenlaw Brook wetland and drainage ditch.

The Risk Assessment evaluated the current risk of a child trespassing on the site and future scenarios of adult and children residing at the site and future Quarry workers. The Risk Assessment concluded that for upper tier soil under maximum exposure scenario both the trespasser and the future resident scenario exceed the EPA target risk range for carcinogenic risks. Using mean contaminant concentration instead of maximum only the future resident scenario exceed the EPA target range. (62:6-8)

The Risk Assessment concluded that for the lower tier soil under maximum exposure concentrations both the trespasser and future resident scenarios exceeded the EPA cancer target risk range. Using mean contaminant concentrations instead of maximum, only the future resident scenario exceeded the EPA target range. (62:6-9)

The selected remedy for the Quarry Site is excavation and use of the excavated material as subgrade fill for on-base landfill cap construction. Also included is the restoration of Quarry wetland and environmental monitoring of the groundwater and Greenlaw Brook wetland. The estimated cost of the remedy is $2,009,100.

Mather Air Force Base, Aircraft Control and Warning Site

Mather AFB is located approximately 12 miles east of Sacramento and due south of Rancho Cordova in Sacramento County California. The base is due south of U.S. Highway 50, a major highway connecting Sacramento and South Lake Tahoe. The Aircraft Control and Warning Site (AC&W) is near the east central part of Mather AFB. (63:2-1)

The nearest residential area, the Mather AFB Base Housing area is 2600 to 3100 feet from the AC&W site. Facilities on the site are used for administrative offices. Recreational uses of land in the immediate vicinity include golfing and trap shooting. (63:2-5)

Surface water in the area drains directly into Morrison Creek and into an unnamed tributary of Morrison Creek (63:2-1).

Mather Lake is the largest surface water feature near the site. It encompasses 64 acres and is about 3000 feet northeast of the site. The lake level is maintained by surface water runoff, by water pumped from Folsom South Canal, and by groundwater pumped into the lake. Several siltation ponds associated with aggregate mining are about 6000 feet north of the site. They contain standing water throughout the year. The ponds are not part of Mather AFB property. (63:2-6)

Groundwater resources in the region of the AC&W site occur in the Shallow Water Bearing Zone (SWBZ), the Lower Water Bearing Zone (LWBZ) of the Laguna Formation and in underlying deeper aquifers in the Mehrten Formation. (63:2-6)

The SWBZ is at least 60 feet in thickness. It has the water table as an upper surface, about 120 feet below land surface, and the top of the LWBZ as a lower boundary. Groundwater from the SWBZ is not currently utilized in the vicinity of the site. (63:2-6)

The top of the LWBZ occurs between 180 to 200 feet below land surface. The base of the LWBZ in the AC&W site area may be defined by a clayey silt layer about 250 feet below land surface. Most of the groundwater pumped by Family Housing area water production wells is from depths greater than 318 feet below land surface, from the deeper aquifers in the Mehrten Formation. (63:2-6)

It has been reported that TCE, used as a solvent and degreaser in facility operations, and waste transformer oil were commonly disposed into a waste disposal pipe in the AC&W site area during the period between 1958 and 1966. The existence of the waste disposal pipe has never been verified. Estimates suggest that about 1200 gallons of TCE, and 1400 gallons of transformer oil may have been disposed in this manner. Three additional releases may have occurred from underground storage tanks. (63:2-7)

TCE has been detected in groundwater ranging from 4 parts per billion (ppb) to 790 ppb in shallow monitoring wells. No significant soil contamination has been found. (63:2-7)

Modeling during the Risk Assessment predicted that the TCE plume is not expected to impact downgradient drinking water wells in the future. The modeling also predicted that

natural attenuation may reduce the maximum exposure concentration to 5 ppb within 20 years (63:2-24). The Risk Assessment concluded that groundwater under current land-use does not present a pathway for exposure. However, in a hypothetical unrestricted residential land-use new drinking wells could be installed into the SWBZ. This would create an excess cancer risk of $1.1X10^{-5}$.

The selected remedy for contaminated groundwater in the SWBZ at the AC&W site consists of groundwater extraction, treatment via air stripping and adsorption of TCE vapor phase by activated carbon, and injection of treated effluent into the SWBZ.

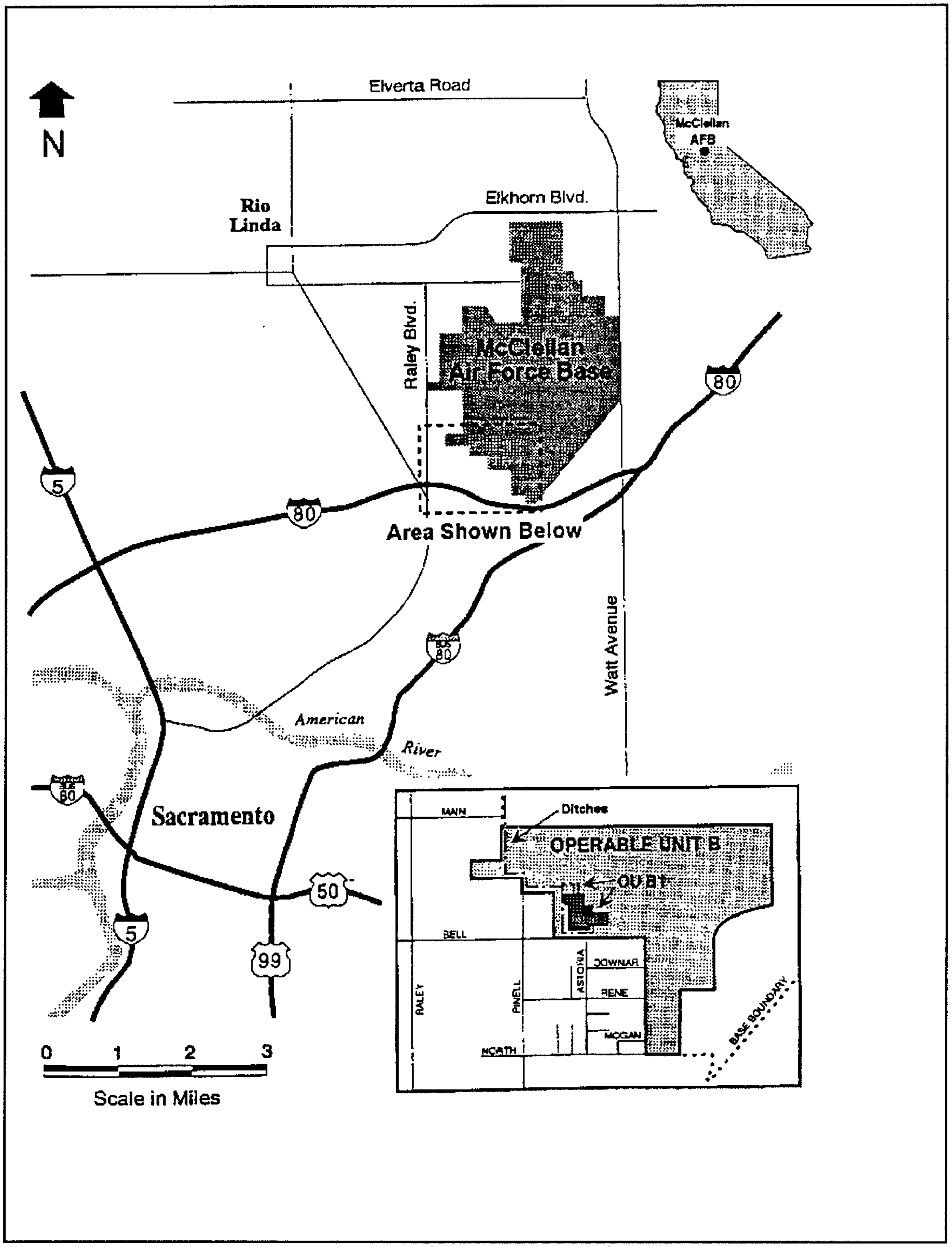
The remediation is estimated to last 10 years at a cost of $4,452,000.

McClellan Air Force Base, Interim Operable Unit B1

McClellan AFB is located in the Sacramento Valley, approximately seven miles northwest of Sacramento, California (64:II-1).

The site is located in the southwest portion of the base and consists of an open storage lot operated by the Defense Reutilization and Marketing Office (DRMO); a former transformer storage, loading, unloading area; the Civil Engineering (CE) Storage Yard; and three drainage ditches that receive surface water runoff from the DRMO storage lot. The site is approximately 18 acres in size (64:II-1).

In the early 1960s, waste oil was applied to soils on the site to suppress dust. The waste oil was collected from



McClellan AFB, Operable Unit B1 Location Map (64:II-3)

various facilities on base. The oil may have consisted of hydraulic oils, degreasing solvents, transformer oils, and automotive oils and fluids. Transformers were stored at the DRMO lot at various times for the 1960s through 1987. North of the storage lot transformers containing oil with PCBs were loaded and unloaded from railroad cars. (64:II-5)

The CE storage yard has been in use since the 1960s. Most of the materials stored in the yard are nonhazardous; however transformers containing PCBs were reportedly stored in the yard some times between 1960 and 1987. By 1977 the yard was paved with asphaltic concrete (64:II-5).

In 1987, 1.5 to 7 gallons of PCB-contaminated oil leaked from a transformer onto the ground in the northern portion of the DRMO storage lot. Contaminated soil in the area was excavated to approximately 10 inches, removed, and covered with clean gravel (64:II-5). In 1992, during the RI of the site, PCB contamination was reported in surface soil in the DRMO yard. A fence was constructed around soil containing at least 100 ppm of PCB to restrict access, and solid metal planking was placed over the area to reduce fugitive dust emissions. In 1993, a 45-mil HDPE plastic liner was placed over the area to control dust and to prevent runoff to a nearby drainage ditch. Access to the DRMO yard was also restricted so that only adults could enter. (64:II-5)

The on-base areas surrounding the site are industrial. Nearby off-base land is zoned residential and light industrial. (64:II-1)

The water table beneath McClellan AFB is typically 100 to 105 feet below ground surface and varies locally because of topography and depressions created by water supply wells. From the water table to a depth greater than 400 feet below ground surface, one aquifer provides water for domestic and industrial uses in the vicinity of McClellan AFB. Beneath the site groundwater flows to the southeast toward a pumping depression created by McClellan AFB and municipal supply wells. (64:II-2)

The communities in the vicinity of McClellan AFB receive potable water from off-base municipal wells. McClellan AFB obtains potable water from on-base wells. The nearest well to the site is McClellan Base Well 18, located approximately 1,000 feet southeast of the site. (64:II-2)

For the last 35 years the site has been used for military purposes and is expected to be used for military, industrial, or commercial purposes in the future. Access is controlled and future exposure is consistent with a limited access industrial setting. (64:II-27)

Testing found polychlorinated biphenyls, dioxins, furans, petroleum hydrocarbons, volatile organic compounds, semi-volatile organic compounds, and inorganic species in the soil, primarily in the near-surface (64:II-9).

Recharge of groundwater by surface water at McClellan AFB is limited due to the extensive paving and storm drainage system, and because of the less permeable shallow hardpan layers that occur in the vadose zone soils (64:II-9).

Groundwater modeling suggests that contaminants discharged at the site will not vertically reach groundwater in measurable concentrations for 30 years or more under current site conditions (64:II-26).

The risk assessment analyzed risks to current workers, current nearby residents, visitors to the site, and a hypothetical future residence constructed on the site in the area of highest PCB contamination (64:II-27).

The calculated RME risk for current worker and current nearby resident are just above the EPA acceptable risk level of 10^{-4} at $3.8X10^{-4}$ and $1.2X10^{-4}$ respectively. The visitor is within the target risk range of 10^{-4} to 10^{-6} at $2.7X10^{-6}$. The case of a future resident on the site calculated to 23 but is reported as 1.0 since a probability cannot exceed 1.0 (64:II-33). The Hazard Index was below 1.0 for every scenario except the future resident where it was 17 (64:II-35).

The selected remedy consists of capping the site with a minimum two-inch thick asphaltic concrete over engineered fill and conducting treatability studies. Sediments in drainage ditches containing contaminants will be excavated and placed under the cap. A trap will be placed in the drainage ditch to collect sediment that may carry adsorbed contaminants. The cap will be maintained and periodically repaired, surface water, soil gas, and groundwater will be monitored, soil treatment technologies will be evaluated. Prior to selection

of a final remedy, institutional controls will be invoked to ensure the site will only be used for industrial activities. (64:II-64)

The cost of the selected interim remedy is estimated at $3,172,000.

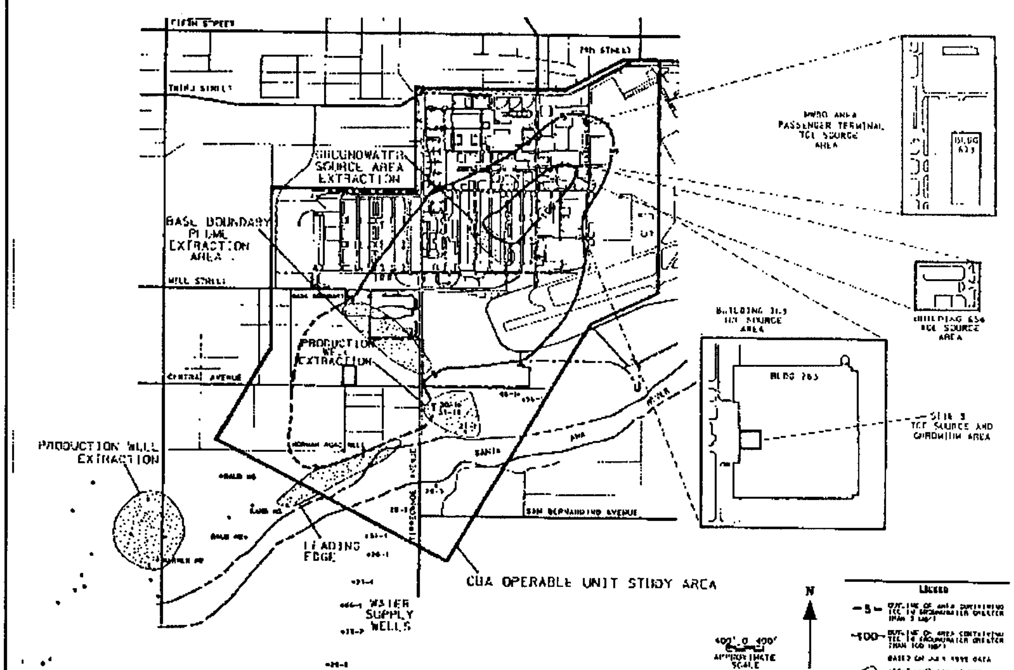
Norton Air Force Base, Central Base Area

Norton AFB is located in the city of San Bernardino, San Bernardino County, California, 55 miles east of Los Angeles and 60 miles west of Palm Springs (65:1-1).

Norton AFB was activated in March 1942 as an engine repair center for aircraft. Solvents, specifically TCE, were used in servicing aircraft from the 1940s to the early 1980s. Former waste disposal, handling, and discharge practices have resulted in soil and groundwater contamination. (65:2-1)

Land surrounding Norton AFB includes areas of residences, light and heavy industry, and agriculture. Residential areas are located to the north and west. Light industrial areas are located to the north and to the southwest. (65:1-1)

Norton AFB is located on a large apron of alluvium, characterized by great thickness, rapid facies changes, and a wide range of fragment sizes. The stratigraphy consists of unconsolidated water-bearing deposits underlain by consolidated, virtually non-water bearing rocks. Sediments underlying the base consist of unconsolidated, relatively undisturbed gravels, sands, silts, and clays. The depositional setting varies across the base. Soils consist of loamy sands and sandy loams. The soils are generally quite



Norton AFB, Central Base Area Operable Unit Location Map
(65:5-2)

permeable and exhibit limited run-off and water erosion potential. (65:1-1)

The groundwater aquifer system beneath Norton AFB is defined by three water-bearing zones and three confining (aquitard) members. The upper confining member, which locally supports perched water zones, covers all but the eastern half of the base. Regional groundwater flows toward the southwest. Recharge is supplied by runoff from the San Bernardino Mountains. The Santa Ana River flows southwest along the southern base boundary. (65:1-3)

The aquifer system provides drinking water in addition to water for agricultural and commercial uses. The upper water-bearing zone has been affected by Norton AFB operations. Drinking water is derived principally from the middle and lower water-bearing zones. The Gage Canal complex, which consists of sixteen active wells located immediately south/southwest of the base has occasionally reported TCE in groundwater samples.

Seven chemicals were identified as contaminants of concern in groundwater. These are benzene, dichloroethane, 1,2-dichloroethylene, tetrachloroethylene, 1,1,1-tricloroethane, TCE, and vinyl chloride. Two chemicals were identified as contaminants of concern in soils; TCE and chromium.

The Risk Assessment uses a maximum exposure scenario for water consumption and soil. The soil exposure assumes that all asphalt and concrete covers were removed above the soil.

Subsurface soils in spill and dump areas would be excavated to a 20-foot depth during a residential setting and a 5-foot depth during a light industrial setting.

The carcinogenic risks for all receptor groups are within EPA's acceptable range of 10^{-4} to 10^{-6} when using EPA factors. When using Cal-EPA factors, however, the residential adult and residential child group exceed the acceptable range for soil ingestion and dermal contact with soils. For noncarcinogens the adverse health effects is primarily due to soil ingestion and dermal contact with chromium. The risk is primarily due to background minerals concentration. For Light Industrial use of the area, all risks are within the acceptable range for both the EPA factors as well as Cal-EPA factors. (65:6-3)

The selected remedies for the groundwater are; deed restriction, groundwater monitoring, groundwater extraction, wellhead treatment or provision of water supplies, treatment by air stripping, direct discharge of emissions to atmosphere, or treatment by vapor-phase carbon adsorption if emissions are not in compliance with air quality ARARs, and reinjection of treated water (65:9-2). Deep subsurface soil will have groundwater monitoring, treatment by in situ Soil Vapor Extraction (SVE), treatment of emissions by vapor-phase carbon adsorption or no treatment if emissions are in compliance with air quality ARARs (65:9-4). Areas where TCE is in the soil; excavation of soil containing TCE above the cleanup standard, backfill of excavation with clean import or borrow soil, transportation onsite to treatment location, treatment by ex

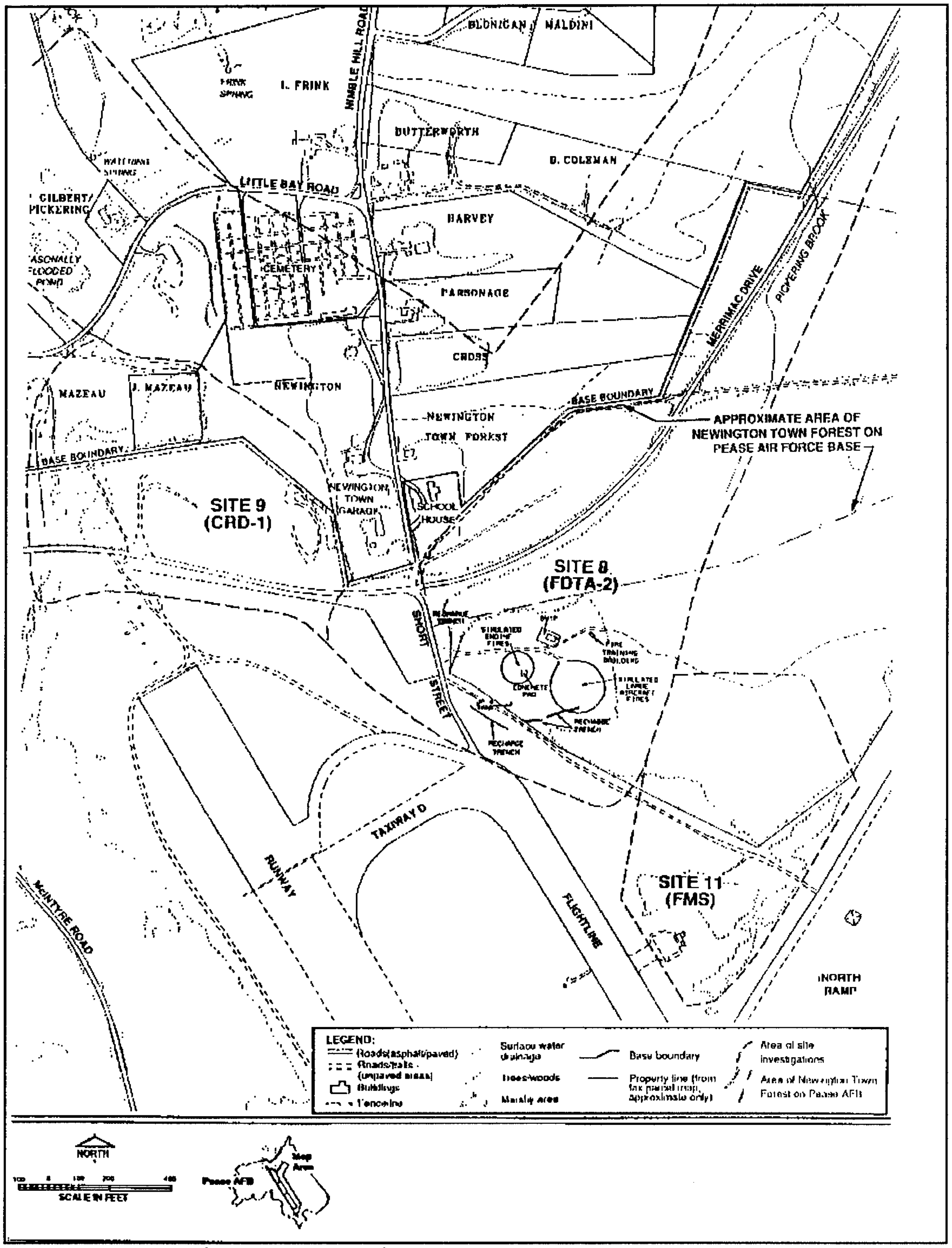
situ SVE, treatment of emissions by vapor-phase carbon adsorption, or no treatment if emissions are in compliance with air quality ARARs, On-base use of treated soil (65:9-5). Areas where TCE and Chromium are in the soil; demolition and reconstruction of existing facilities, excavation of soil containing TCE and chromium commingled above the cleanup standards, backfill of excavation with clean import or borrow soil, testing of excavated soil, transportation of soil off-site by licensed transporter, disposal off-site to licensed Subtitle C disposal facility (65:9-8).

The total cost will be $39,302,260 excluding emission control which would add an additional $11,942,580 to the cost.

Pease Air Force Base, Site 8

Pease AFB is located in the Towns of Newington and Greenland and in the City of Portsmouth, in Rockingham County, New Hampshire. The Base is located on a peninsula in southeastern New Hampshire. The peninsula is bounded on the west and southwest by Great Bay, on the northwest by Little Bay, and on the north and northeast by the Piscataqua River. The City of Portsmouth is located east and southeast of the base. Pease AFB occupies 4,365 acres and is located approximately in the center of the peninsula. (66:1)

The site is the former fire-fighting training area and is located in the northern portion of the base. The site was active as a fire training area from 1961 to 1988. The majority of training exercises were performed in a large circular pit area located in the southeastern portion of the



Pease AFB, Site 8 Location Map (66:9)

site. Prior to 1971, mixed waste oils, solvents, and fuels were collected from across the base. The pit area was first presaturated with water, then the waste oils etc. was poured on top of the water and onto mock aircraft. The mixture was allowed to burn for 1 to 2 minutes and then extinguished using an aqueous film-forming foam. (66:6)

In the mid 1970s the practice of using mixed wastes was ceased and only JP-4 was used. In 1974, the pit was refurbished with a underground sprinkler system to allow JP-4 to be sprayed onto the pit area through an underground fuel line and an 8-inch-diameter drain was constructed at the edge of the burnpit. Excess fuels and fire training materials eventually discharged through this pipe into a drainage ditch at the northern end of the site. (66:13)

There are approximately 3,700 dwellings within a 1-mile radius of Pease AFB, a number of these dwellings have wells and/or springs located on their associated properties. (66:2)

Surface drainageways at Pease AFB flow radially away from the center of the peninsula, into Great Bay toward the west, Little Bay to the northwest and north, and the Piscataqua River to the east (66:2). Pickering Brook is the primary surface water pathway that carries runoff away from the site area toward the Piscataqua River (66:5).

An RI study of the site concluded that the former burn areas were potential source areas for volatile organic compounds. In February and March 1990, a IRM removed approximately 262 tons of contaminated soil from a drainage

ditch which received surface runoff from the main burn pit. This was to prevent migration of contaminants from the ditch soil to deeper soil and groundwater. (66:14)

In August 1990, a second IRM began operation. This was a Groundwater Treatment Plant (GWTP) designed to initiate control of dissolved VOC migration and to evaluate a pump-and-treat system as a potential source control measure. (66:14)

The GWTP included extraction wells, oil/water separation, metals precipitation, flocculation, clarification, bag filtration, air stripping, liquid-phase carbon adsorption, and subsurface recharge trenches. The effluent meets drinking water standards. (66:15)

In general, the maximum extent of soil contamination is within 500 feet of the burn area, as measured horizontally, and from the surface to approximately 30 feet below ground surface vertically. The majority of soil contamination consists of aromatic hydrocarbons and total petroleum hydrocarbons (TPHs). (66:18)

Groundwater in both the overburden and bedrock water-bearing zones have been impacted. In the overburden, two distinct plumes are present. The first is a plume of free-phase product that is floating on the ground water surface. The second plume contains dissolved contaminants and extends from the former burn area across the base boundary and under Newington Town property. In bedrock a plume of dissolved VOC contamination has been detected that extends northwest off base onto Newington Town property. (66:18)

Pesticides, polynuclear aromatic hydrocarbons (PAHs) and metals were detected in Pickering Brook. Low levels of VOCs and PAHs also were detected in the sediment from Knights Brook. (66:18)

The risk assessment considered both current and future use of the land for each medium. Future land-use within base boundaries was assumed to continue as industrial, although future residential development may occur off-base. The groundwater in the general area is not currently used, but could potentially be used for drinking or other purposes in the future. (66:61)

Using a maximum exposure scenario, a future Maintenance worker exposed to soil up to 15 feet deep would have a total lifetime cancer risk of $9X10^{-5}$ (66:E-36). A future off-base resident would experience a total lifetime cancer risk of $4X10^{-5}$ or $3X10^{-3}$ from using groundwater in the overburden or bedrock respectively. The future off-base residents would also have a Hazard Index of 20 and 40 for use of the groundwater in the overburden and bedrock respectively (66:E-37). The risks from Pickering and Knights Brooks are all below 10^{-6} cancer risk and 1.0 Hazard Index (66:E-38).

The selected remedy consists of: In situ Soil Vapor Extraction (SVE) treatment of contaminated soil, treatment of extracted soil vapor for removal of volatilized organics, construction of an asphaltic concrete cap to minimize infiltration into the SVE treatment, recovery and off-base disposal of free-phase product floating on the ground water

surface, extraction of overburden groundwater, construction of a long-term GWTP, discharge of treated groundwater in subsurface recharge trenches, and long-term environmental monitoring
(66:83).

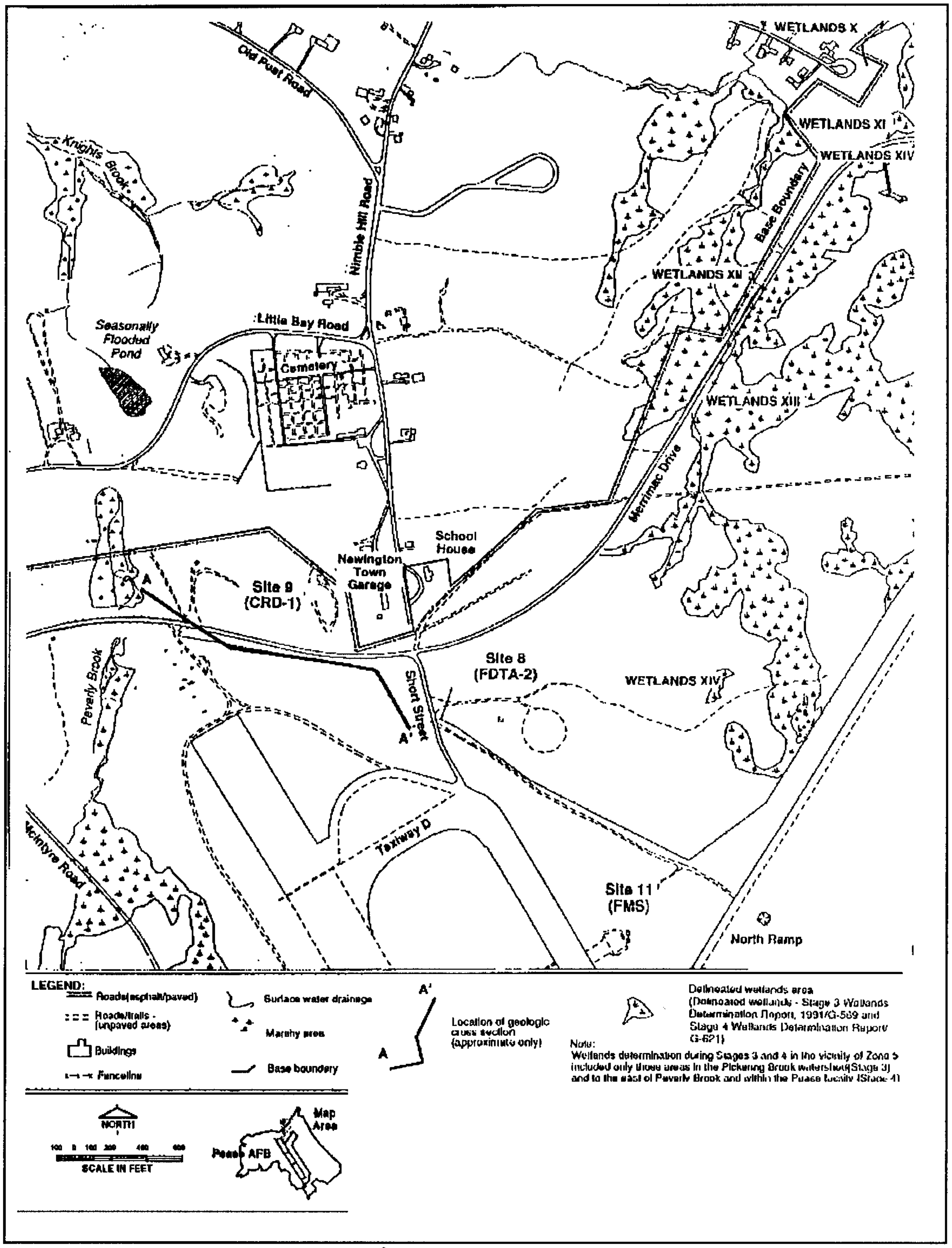
The estimated cost of the selected remedy is $14,525,219.

Pease Air Force Base, Zone 5

Pease AFB is located in the Towns of Newington and Greenland and in the City of Portsmouth, in Rockingham County, New Hampshire. The Base is located on a peninsula in southeastern New Hampshire. The peninsula is bounded on the west and southwest by Great Bay, on the northwest by Little Bay, and on the north and northeast by the Piscataqua River. The City of Portsmouth is located east and southeast of the base. Pease AFB occupies 4,365 acres and is located approximately in the center of the peninsula. (66:1)

There are approximately 3,700 dwellings within a 1-mile radius of Pease AFB, a number of these dwellings have wells and/or springs located on their associated properties. (66:2)

Surface drainageways at Pease AFB flow radially away from the center of the peninsula, into Great Bay toward the west, Little Bay to the northwest and north, and the Piscataqua River to the east (66:2). Pickering Brook is the primary surface water pathway that carries runoff away from the site area toward the Piscataqua River (66:5).



Pease AFB, Zone 5 Location Map (67:5)

The site includes areas in the northern portion of Pease AFB including the Construction Rubble Dump and Fuel Maintenance Squadron Equipment Cleaning Site. (67:1)

The Construction Rubble Dump served as a soil borrow area and disposal site for construction debris, including concrete, asphalt, wood, tree stumps, brush, and scrap metal. It is bordered by Merrimac Drive to the south and the base boundary to the north. The western boundary is defined by the emergent wetlands that drain southwest, toward Peverly Brook. (67:11)

The area is not currently in use and airfield clear zone restrictions prevent the construction of residential, commercial or industrial buildings at the site. (67:12)

Studies suggest that prior to 1971, solvents used to remove coatings from aircraft parts may have been intermittently disposed of at the Fuel Maintenance Squadron Equipment Cleaning Site. Areas appear to have stressed vegetation (67:15). The site is not currently in use. Airfield clear zone restrictions also prevent the construction of residential, commercial or industrial buildings at this site. (67:16)

The soil quality at the Construction Rubble Dump does not appear to have been significantly affected by the construction debris or site activities (67:35). VOCs were detected in the soil at low concentrations. One location contained TPHs at a concentration above background concentrations. (67:36) Low concentrations of VOC observed in groundwater appear to be

related to another site and will be treated as part of that remedial action (67:39).

At the Fuel Maintenance Squadron Equipment Cleaning Site no discrete, contaminant source was identified. Sampling concluded the groundwater quality has not been affected by past site activities. (67:40)

The Risk Assessment looked at current and future use scenarios. Since the sites proximity to the runway, it was assumed that all future use will be commercial or industrial. The Assessment calculated all cancer risks to be within the EPA acceptable risk range of 10^{-4} to 10^{-6} with the exception of exposure to overburden groundwater where the risk reached $1X10^{-4}$. More than 99% of the risk reflected the presence of arsenic. Arsenic is naturally occurring in Pease AFB soil, and it was detected at concentrations below the MCL. All Hazard Indices were less than 1.0. (67:43)

Since the Risk Assessment concluded the site does not pose current or potential future threat to human health a No Action remedy was selected for the site. (67:45)

Plattsburgh Air Force Base, LF-022

Plattsburgh AFB is located in Clinton County in northeastern New York State, bordered on the north by the City of Plattsburgh, on the south and west by the Town of Plattsburgh, and on the east by Lake Champlain. Landfill LF-022 is located west of the runway approximately 500 feet from the western Plattsburgh AFB boundary. (68:1-1)

Access to the landfill from the east and north is restricted because the site is bordered on two sides by controlled access areas, the active runway to the east and the small arms range to the northwest. Access from the south and west is somewhat less restricted, but is limited by an intact 4-foot-high, three-wire fence posted with "No Trespassing" signs. This area is patrolled regularly by Plattsburgh AFB security personnel. Vehicles can access the landfill using a road leading from the western Perimeter Road, which is within the controlled access flightline area. (68:1-1)

The landfill received domestic wastes from Plattsburgh AFB for disposal from 1959 to 1966. Daily operations consisted of digging 25-foot-deep trenches, spreading and burning the trash in the trenches, and covering with sandy soil. Explosive ordnance was deactivated or detonated on base; residue was then disposed of in the landfill as "nonhazardous waste". Because appropriate methods of hazardous waste disposal were available during the landfill operation, it is unlikely that hazardous wastes were disposed of in LF-022. The maximum volume of fill is estimated at 524,000 cubic yards. Since landfilling operations ceased, vegetative growth (trees and brush) covers the site. (68:2-1)

LF-022 is approximately 1,350 feet north of a small mobile home development. The nearest on-base housing is more than 6,000 feet east of the site. A light industrial area is located approximately 700 feet west of the site. (68:1-1)

Site topography slopes gradually toward the east and southeast with a surface gradient between 0 and 3 percent. The site's northern boundary has a steep descending slope into a natural depression area. There are no surface water features within the LF-022 site. However, groundwater may collect in a natural depression approximately 600 feet north of the site during spring runoff. (68:1-1)

Site geology consists of approximately 80 feet of sand, 10 feet of clay, and 30 feet of till overlying carbonate bedrock. Two aquifers at the site include an unconfined aquifer in the sand unit on which LF-022 was constructed and a confined aquifer in the bedrock. The groundwater surface in the unconfined aquifer is approximately 30 feet below the depth of waste and the upper surface of the confined aquifer in the bedrock is approximately 125 feet below the depth of waste. Groundwater in the unconfined aquifer flows east toward Lake Champlain and dominates local flow patterns at the site. LF-022 is located on a topographic high on the western side of the base, which also affects local groundwater flow. Groundwater in the confined aquifer also flows east toward Lake Champlain. (68:1-5)

Surface soil samples detected no VOC or SVOCs above background levels. Organochlorine pesticide dichlorodiphenyltrichlorethane (DDT) and the associated analogs dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethene (DDE) were identified as site surface soil contaminants. Lead was detected at

concentrations above background levels in soil collected just below the waste. Iron and manganese were detected in groundwater at concentrations exceeding New York State groundwater quality standards. (68:5-4)

In the risk assessment, based on current site uses, surface soil is the only media to which individuals could be exposed. Groundwater is not used as a drinking water source downgradient of the site. Exposure to groundwater was assessed as a future risk. The only risk under current site conditions is ingestion of and direct contact with surface soil by a child trespasser. Three future risks were assessed 1) ingestion and contact with groundwater by a future resident, 2) ingestion and direct contact with surface soil by a future resident, and 3) inhalation of vapors and fugitive dust by a future resident. (68:6-4)

All estimated total site risks for the one current and three future exposure scenarios were at or below EPA target risks with the exception of a child assumed to be simultaneously exposed to surface soil, groundwater, and fugitive emissions. This elevated risk is mostly associated with ingestion of manganese in groundwater. The risk assessment concludes that current and future site conditions do not indicate a significant risk to human health. (68:6-11)

The selected method of remediation is Site Grading and Vegetation establishment consisting primarily of placing 12 inches of soil over the landfill and planting it with grass. Institutional controls will be incorporated to ensure that

future owners will be made aware of the landfill location and that the integrity of the final cover must not be compromised. (68:10-2)

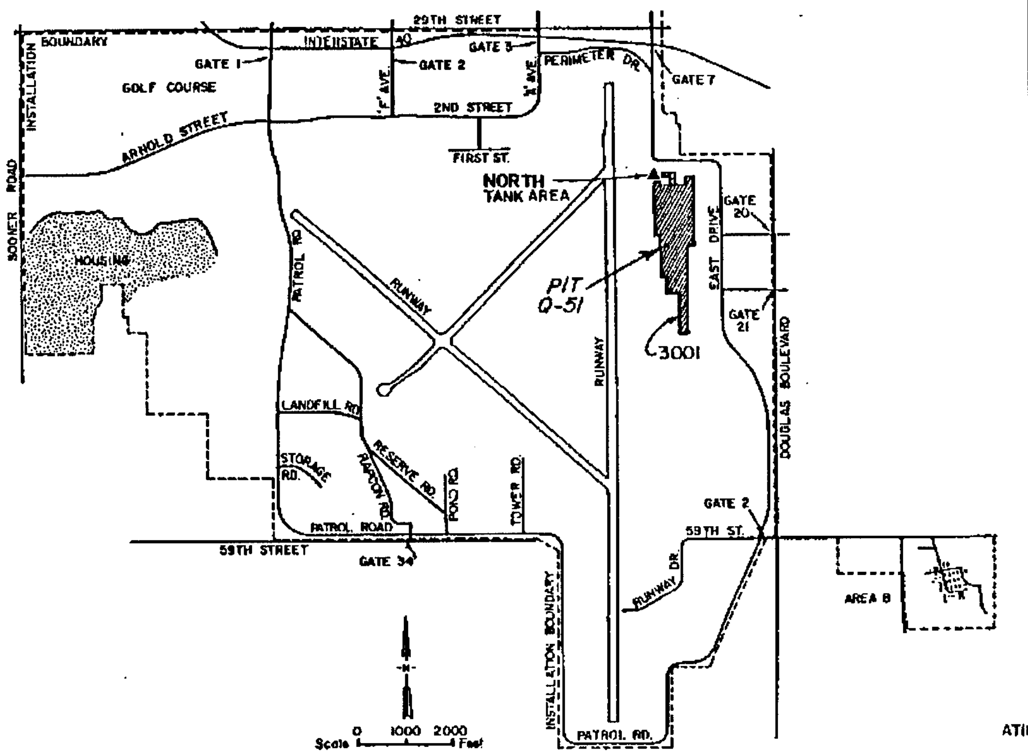
The cost of the selected remedy is estimated to be $2,803,164.

Tinker Air Force Base, Building 3001

Tinker AFB is located southeast of the Oklahoma City metropolitan area, bordering Del City on the west and MidWest City on the north. The main portion of Soldier Creek is to the east of Tinker AFB. Two unnamed tributaries originate on the base and flow into Soldier Creek. The Tinker Air Force Base site has been divided into three operable units, 1) Building 3001, includes the groundwater below building 3001; 2) Soldier Creek, includes Soldier Creek sediment and surface water; and 3) Soldier Creek groundwater. (70:1-1)

Tinker AFB is a major industrial complex for overhauling, modifying, and repairing military aircraft, aircraft engines, and accessory items.

The site lies within the limits of the Garber-Wellington Groundwater Aquifer Basin. Regionally, this is the single, most important source of potable groundwater in the Oklahoma City metropolitan area. The four aquifer zones present in the area of the operable unit from the shallowest to the deepest are the perched aquifer where present, the top of regional aquifer zone, the regional aquifer zone, and the producing zone. The perched aquifer is not a source of drinking water. The top of regional and regional aquifer zones may be



Tinker AFB, Building 3001 Operable Unit Location Map
(69:3)

potential sources of drinking water. The producing zone is a source of drinking water for the area. (70:1-4) The recharge area covers the eastern half of Oklahoma County including Tinker AFB (69:7).

The site is located near the northeast boundary of the Base and consists of a groundwater contaminant plume which covers an area of approximately 220 acres. It includes Building 3001, and the North Tank Area.

Building 3001 houses an aircraft overhaul and modification complex. Subsurface contamination occurred primarily by leakage from the subsurface pits and trenches, erroneous discharging of solvents or wastewaters into storm drains, accidental spills, and/or improper connections between wastewater and storm drains. (69:1)

Building 3001 is an industrial site. The Base is bordered on the north and northeast by urban communities. The south boundary area is adjacent to the General Motors Plant, an industrial complex. Lake Stanley Draper is located southeast of the Base. The remaining areas to the south and east are primarily agricultural. (69:5)

There are 25 water supply wells located on Tinker AFB. In late 1983 routine testing indicated the presence of both trichloroethylene and tetrachloroethylene in wells 18 and 19. Studies concluded that contaminants were entering both wells through corrosive holes in the upper zones, travelling downward through the casing as well as through the annular

space. Both wells were plugged in 1986. In 1988, well 17 was also plugged. (69:16)

Thirty two chemical constituents were identified in the groundwater contaminate plume. Trichloroethylene and chromium are the primary contaminants of concern because they pose the greatest risk to the public and they had the highest concentrations and frequency in the contaminant plume. (69:20)

The ROD stated, unless remedial action is taken, the contamination in the perched zone and upper zone of the regional aquifer would eventually migrate into the lower zones and contaminate the Base's water supply.

The Risk Assessment indicated a carcinogenic risk from drinking the contaminated groundwater over a 70-year exposure period of $1.2X10^{-5}$. This is within the acceptable risk range of 10^{-4} to 10^{-6} used by the EPA.

The selected remedy includes approximately 128 groundwater collection wells, treatment by air stripping for organics removal, a precipitation process for metals removal, and a fine filtration process for the remaining organics and metals. This will result in a reduction of the carcinogenic risk to $1.2X10^{-7}$. In addition, the cleanup will also include removal, disposal and cleaning of a waste pit in Building 3001 and installation of a free floating fuel recovery system in the North Tank Area to remove free floating fuel from the groundwater surface.

The estimated total cost of the remedy is $21,526,440.

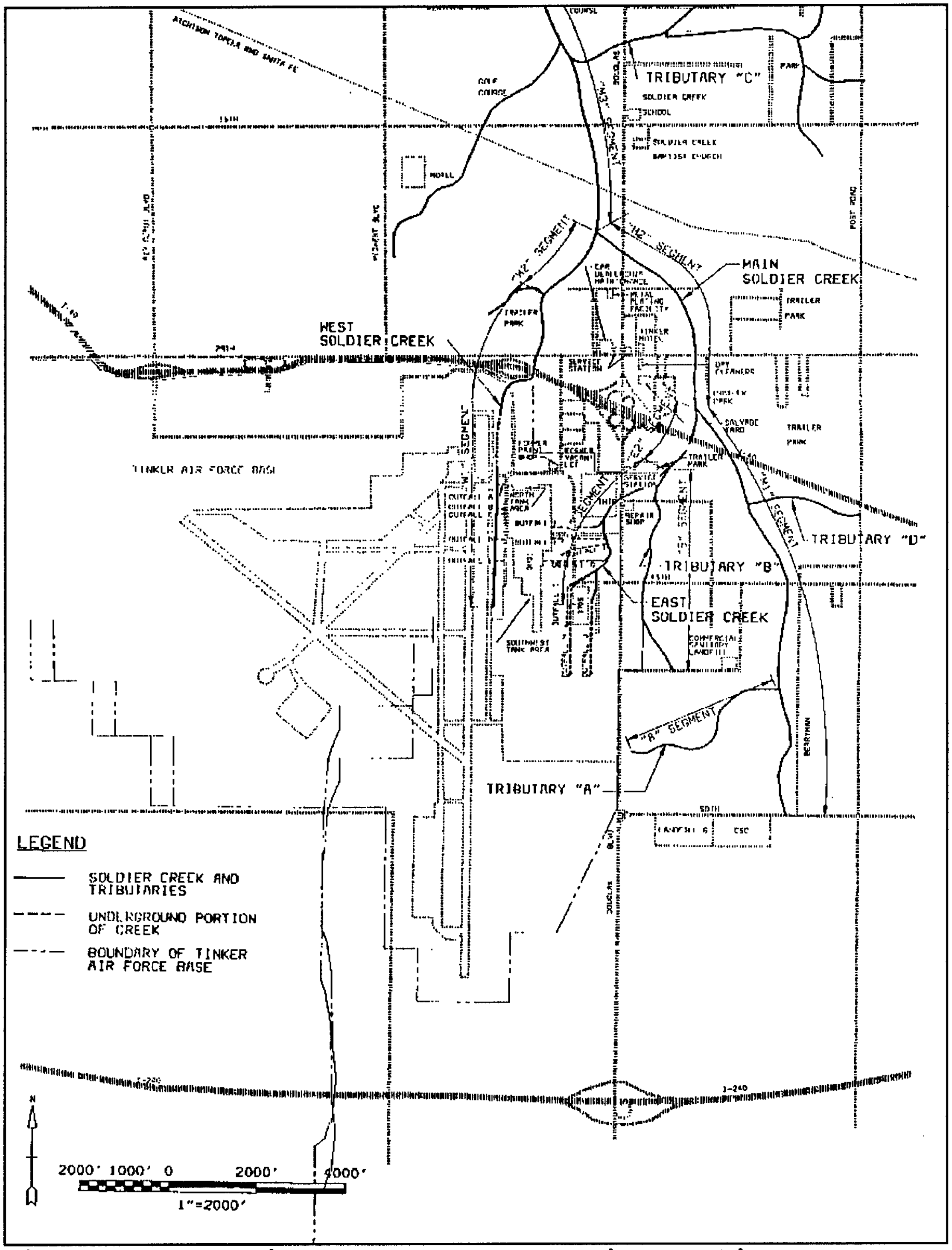
Tinker Air Force Base, Soldier Creek

Tinker AFB is located southeast of the Oklahoma City metropolitan area, bordering Del City on the west and MidWest City on the north. The main portion of Soldier Creek is to the east of Tinker AFB. Two unnamed tributaries originate on the base and flow into Soldier Creek. The Tinker Air Force Base site has been divided into three operable units, 1) Building 3001, includes the groundwater below building 3001; 2) Soldier Creek, includes Soldier Creek sediment and surface water; and 3) Soldier Creek groundwater. (70:1-1)

Tinker AFB is a major industrial complex for overhauling, modifying, and repairing military aircraft, aircraft engines, and accessory items.

Soldier Creek is primarily used for aesthetics and limited recreation. The creek and its branches are bordered mainly by recreational and residential areas with some areas supporting commercial and industrial uses. The areas east of the base are used primarily for agriculture. (70:1-4)

The site lies within the limits of the Garber-Wellington Groundwater Aquifer Basin. Regionally, this is the single, most important source of potable groundwater in the Oklahoma City metropolitan area. The four aquifer zones present in the area of the operable unit from the shallowest to the deepest are the perched aquifer where present, the top of regional aquifer zone, the regional aquifer zone, and the producing zone. The perched aquifer is not a source of drinking water. The top of regional and regional aquifer zones may be



Tinker AFB, Soldier Creek Operable Unit Location Map
(70:1-3)

potential sources of drinking water. The producing zone is a source of drinking water for the area. (70:1-4)

The contamination could have come from one or more of 14 underground storage tanks and solvent pits that used to be located in the vicinity or industrial cross-connections in Building 3001 prior to 1990 that may have been contaminating the storm-water system. (70:2-1)

Accidental spills of chemical substances may have occurred at on-base or off-base location within the Soldier Creek drainage system. Several potential off-base contamination sources exist including underground storage tanks associated with service stations, a salvage yard, auto repair shop, paint shop, and a vacant lot north of Tinker AFB that contains dumped materials. (70:5-1)

Fourteen volatile organics, 29 semi-volatile organics, and 20 inorganics were detected in sediment samples collected from Soldier Creek and its tributaries. At the same locations, 15 volatile organics, 5 semi-volatile organics, and 21 inorganics were detected in surface water samples. (70:5-8)

The Risk Assessment quantified present and potential future risks to human health that may result from exposure to the contaminants of concern found at the site (70:6-9). The results indicate that all noncarcinogenic risks are less than a Hazard Index (HI) of 1.0 (70:6-13). All carcinogenic risks were less than 10^{-6}, generally considered to be an acceptable risk range (70:6-16). The risk assessment concluded that the

sediments and surface water do not present a treat to human health or the environment.

The selected remedy consists of implementing a five-year environmental monitoring program of the Soldier Creek sediment and surface water.

The estimated cost of the selected remedy is $647,350.

Williams Air Force Base, Operable Unit 1

Williams AFB is located just east of Chandler, Arizona in Maricopa County, and approximately 30 miles southeast of Phoenix. It is surrounded primarily by agricultural land predominantly citrus, cotton, and alfalfa. Small urban areas such as Mesa, Chandler, Gilbert, and Apache Junction are located 5 to 15 miles northeast and northwest of the base. Queen Creek and Chandler Heights are approximately 5 miles south and west of the base respectively. The Base consists of 4,127 acres and served as a flight training base since 1949. (71:2-1)

There are no major surface water bodies within a 10-mile radius of the Base. There are at least 90 domestic wells within a 3-mile radius of the Base. (71:2-2)

Because of a decline in the water table produced by excessive irrigation withdrawals over the past 50 years, an extensive vadose zone has been produced in the vicinity of Williams AFB. The low rainfall and high evapotranspiration rate of the area also contribute to a very low potential for recharge to occur through the soil comprising the vadose zone. Groundwater is encountered at depths ranging from 180 to 250

feet. The two zones of the aquifer are considered to be part of the same aquifer system and are referred to as the Upper and Lower portions of the aquifer. The groundwater flows to the north and east of the base. (71:2-4)

Operable Unit 1 is comprised of the 10 individual sites listed below:

- Landfill
- Fire Protection Training Area No. 1
- Northwest Drainage System
- Radioactive Instrumentation Burial Area
- Pesticide Burial Area
- Hazardous Materials Storage Area
- 5 USTs, Building 789
- 2 USTs, Building 725
- 2 USTs, Building 1086
- 3 USTs, Building 1085

Landfill

The landfill is located in the southwest corner of the Base. It operated from 1941 to 1976. The landfill was constructed by digging unlined trenches 15 to 20 feet deep and then filling them with refuse to approximately 10 to 15 feet above the original ground level (71:2-7). It received mainly domestic trash and garbage. It also received wood, metal, brush, and construction debris. It is also possible that solvents, and chemicals may have been disposed along with the trash. Prior to 1973, dried sludge from the sewage treatment plant was also taken to the landfill. Testing detected

pesticides, SVOCs, beryllium, lead and zinc in the surface soil. A total of 59,000 cubic yards of surface soil is estimated to be contaminated. (71:4-2)

Groundwater sampling found organic and inorganics above background concentrations.

The Risk Assessment considered three major categories of use; current resident, future resident, and current occupational. No incremental lifetime cancer risk was above 10^{-4}. Incidental ingestion of soil by current and future residents had a Hazard Index of 1.21 above the 1.0 standard. Ingestion of groundwater by future residents had a Hazard Index of 6.71. (71:5-20)

The selected remedy to be used at the landfill includes installing a permeable cap over the contaminated surface soils, installing an interceptor trench around the perimeter of the capped area, erecting a fence around the perimeter of the interceptor trench, and imposing land-use restrictions to protect the integrity of the landfill cover and operation of the groundwater monitoring system. (71:8-1)

The total cost for the remedy is approximately $3,757,481. (71:8-4)

Fire Protection Training Area No. 1

The site was reportedly used for fire training in which fuel, waste oils, solvents, and other flammable materials were burned during the training exercises. Any residual materials and fire extinguishing agents may have volatilized or percolated into the ground. Training operations at the site

were believed to have started in the early 1940s and were concluded in 1958. (71:2-8)

Soil and groundwater investigations indicate that soil and groundwater at the site have not been impacted above acceptable health levels and is considered a no further investigation site. (71:4-2)

Northwest Drainage System

Includes the old and existing northwest drainage ditches. The old ran southwest across what is now Base housing and is now filled. The existing is located in the northwest corner of the Base. The channel is approximately 2,100 feet long, 20 feet wide and 5 feet below grade. They may have received spills of aircraft washing solution and shop wastes from the flightline. (71:2-10)

Four inorganics were detected in the soil above background levels. The groundwater was not monitored since there is no indication of a pathway to the groundwater from the suspected soil (71:4-3).

The Risk Assessment found no incremental lifetime cancer risk above 10^{-4} and no Hazard Index above 1.0 (4:5-2). Therefore remedial action is not necessary and no further action is required.

Radioactive Instrumentation Burial Area

The site covers approximately 100 square feet and is located near the southern edge of the Base. Until approximately 1958, it was common practice for the Air Force to bury dials painted with radium-luminous paint, electron

tubes, radium-bearing parts and other instruments with low-level radioactive content. The instruments were reported placed in a drilled hole and then the holes were filled with cement. In December of 1992, a removal action was completed at the site (71:2-12). Soil samples found radiation to be within the possible range of background activities in the U.S. soils, particularly where uranium minerals are present. (71:4-4)

Pesticide Burial Area

The Pesticide Burial Area is located in the southwest corner of the Base. The site is less than .4 acre and is approximately 1,500 feet south of Base housing. Between 1968 and 1972, drums containing unused or outdated pesticides were buried at this site and signs erected marking the general location. Types and quantities buried were not documented. (71:2-12)

Acetone, methylene chloride, and bis(2-ethylhexyl)phthalate were detected in samples from soil borings at the site. Antimony was the only inorganic constituent detected above background concentrations. (71:4-4)

The Risk Assessment found no incremental lifetime cancer risk above 10^{-4} and no Hazard Index above 1.0 (71:5-2). Therefore remedial action is not necessary and no further action is required.

Hazardous Materials Storage Area

The Hazardous Materials Storage Area is located near Building 1090 in an unmarked area approximately 30 feet by 40

feet. Paints, solvents, caustics, and other materials used for maintenance operations were stored in this area from 1959 until it was abandoned in 1983. As a result, this area is a suspected location for minor spillage or leakage of hazardous wastes. (71:2-13)

Various VOCs and SVOCs were detected in the soil. Beryllium and copper were the only metals detected above background concentrations. (71:4-4)

The Risk Assessment found no incremental lifetime cancer risk above 10^{-4} and no Hazard Index above 1.0 (71:5-2). Therefore, remedial action is not necessary and no further action is required.

USTs, Building 789

Four 12,000 gallon and one 1,000 gallon USTs were located at the former Base Motor Pool. The four 12,00 gallon tanks were used to store gasoline and diesel for the motor pool. The 1,000 gallon tank, was a waste oil tank connected to a sump in the concrete slab at the motor pool. The tanks were installed in 1941 and abandoned in the early 1950s. In 1990 the tanks were removed (71:2-15). 1991 testing detected ethyl benzene and xylene in the soil (71:4-4).

The Risk Assessment found no incremental lifetime cancer risk above 10^{-4} and no Hazard Index above 1.0 (71:5-2). Therefore, remedial action is not necessary and no further action is required.

USTs, Building 725

A 12,000 gallon UST used to store gasoline and a 1,000 gallon tank believed to contain waste oil were installed at the site of the old Higley gas station before 1938 and abandoned around 1954. The tanks were removed in 1990. (71:2-16) Ethyl benzene and xylene were detected in the soil (71:4-5).

The Risk Assessment found no incremental lifetime cancer risk above 10^{-4} and no Hazard Index above 1.0 (71:5-2). Therefore, remedial action is not necessary and no further action is required.

USTs, Building 1086

These are two 5,000 gallon tanks constructed of precast concrete halves joined at the centerline and sealed with a rubber gasket. The tanks received wastes from the paint stripping shop. In 1987 an investigation indicated one of the tanks was leaking. In 1987 the tanks were removed. (71:2-17) Testing indicated methylene chloride and THP in the soil (71:4-5).

The Risk Assessment found no incremental lifetime cancer risk above 10^{-4} and no Hazard Index above 1.0 (71:5-2). Therefore, remedial action is not necessary and no further action is required.

USTs, Building 1085

Two 600 gallon precast concrete tanks received wastes from a metal plating shop. One 280 gallon steel tank received used cutting oil and solvents from an accessory repair shop.

(71:2-18) The tanks were removed in 1990. Soil samples indicated organic and inorganic contamination (71:4-6).

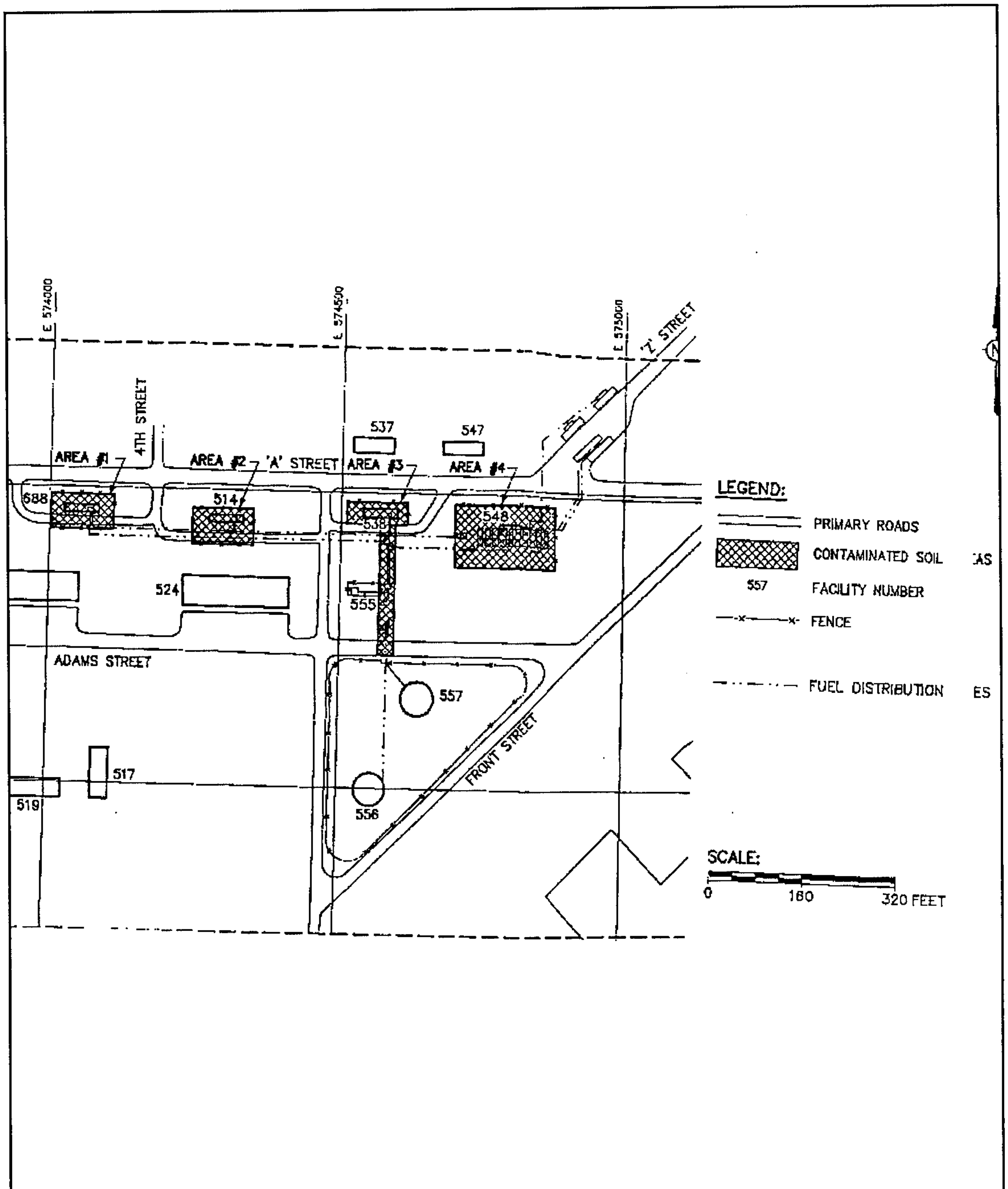
The Risk Assessment found no incremental lifetime cancer risk above 10^{-4} and no Hazard Index above 1.0 (71:5-2). Therefore, remedial action is not necessary and no further action is required.

Williams Air Force Base, Operable Unit 2

Williams AFB is located just east of Chandler, Arizona in Maricopa County, and approximately 30 miles southeast of Phoenix. It is surrounded primarily by agricultural land predominantly citrus, cotton, and alfalfa. Small urban areas such as Mesa, Chandler, Gilbert, and Apache Junction are located 5 to 15 miles northeast and northwest of the base. Queen Creek and Chandler Heights are approximately 5 miles south and west of the base respectively. The Base consists of 4,127 acres and served as a flight training base since 1949. (71:2-1)

There are no major surface water bodies within a 10-mile radius of the Base. There are at least 90 domestic wells within a 3-mile radius of the Base. (71:2-2)

Because of a decline in the water table produced by excessive irrigation withdrawals over the past 50 years, an extensive vadose zone has been produced in the vicinity of Williams AFB. The low rainfall and high evapotranspiration rate of the area also contribute to a very low potential for recharge to occur through the soil comprising the vadose zone. Groundwater is encountered at depths ranging from 180 to 250



Williams AFB, Operable Unit 2 Location Map (72:4-2)

feet. The two zones of the aquifer are considered to be part of the same aquifer system and are referred to as the Upper and Lower portions of the aquifer. The groundwater flows to the north and east of the base. (71:2-4)

Operable Unit 2 is located at the Base's Liquid Fuels Storage Area and defined as the groundwater and the first 25 feet of soil at the site. (72:1-1)

Liquid fuels have been stored at the site since 1942. Primary storage was in a series of underground storage tanks. Aboveground storage tanks were constructed in 1954 and 1962. The underground storage tanks were closed in August 1988 and during late 1990 and early 1991 were removed. (72:2-5)

Thirty-six groundwater monitoring wells have been installed at the site. The floating free-phase product varies in thickness from a sheen to approximately 15 feet. (72:2-6) The potential risk to human health is from groundwater and soil contamination from JP-4 fuel. (72:4-1)

Of the 36 organic chemicals and metals detected in the groundwater, 21 were identified as chemicals of potential concern. Of the 28 organic chemicals and metals detected in subsurface soil, 19 were identified as chemicals of potential concern. Of the 29 organic chemicals and metals detected in the surface soil, 6 were identified as chemicals of potential concern. (72:5-1)

The Risk Assessment considered under the current land-use scenario incidental ingestion of soil, dermal contact with soil, and inhalation of fugitive dust. Since there are

currently no production wells in the contamination area, no pathway for groundwater was evaluated under the current land-use scenario. (72:5-3) Because the area is currently fenced the potential for a trespasser to contact this area is extremely low (72:5-4).

The future land-use scenario considered residential land-use with ingestion of groundwater, inhalation of chemicals volatilized from groundwater during household water use, incidental ingestion of soil, and dermal contact with soil. (72:5-3)

Groundwater Modeling indicates that potential future migration of the chemicals are not expected to affect any existing Base production wells. (72:5-3)

Under current land-use scenario the greatest incremental lifetime cancer risk is $5.9X10^{-6}$ from ingestion of soil due to beryllium. This is within the EPA target level of 10^{-4} to 10^{-6}. In addition, the incremental lifetime cancer risk from naturally occurring beryllium in the surface soil is $2.5X10^{-6}$ in this area. The next highest risk for the current land use is $1X10^{-9}$ associated with the soil ingestion of bis(2-ethylhexyl)phthalate. (72:5-8)

Under future residential use the greatest incremental lifetime cancer risk is $6X10^{-5}$ associated from benzene in drinking water. This assumes a residential well in the unremediated plume used at those levels for 30 years. The next highest risk is $1.2X10^{-5}$ from ingestion of beryllium in the soil. The risk associated with the background level of

beryllium is $5.2X10^{-6}$. For noncarcinogenic risks the Hazard Index does not exceed 1.0 for any risk under current land use (72:5-9). The total groundwater Hazard Index associated with future residential well use is 12. This exceeds the standard of 1.0. (72:5-9)

The selected remedy includes: Free-phase product and groundwater extraction through horizontal or vertical wells, separation of free-phase product by oil/water separator, pretreatment of the extracted groundwater as needed, treatment of groundwater by air stripping, posttreatment of groundwater as needed, reinjection of treated groundwater, bioenhanced soil vapor extraction for the first 25 feet of soil, treatment of soil vapor and air stripping emissions by either fume incineration or carbon adsorbtion, and restriction on installation of new wells and limiting soil excavation to 10 feet of depth at the site. (72:6-6) The estimated cost of the remedy ranges from \$10,269,006 to \$27,332,727 depending on the selection of horizontal vs vertical wells and fume incineration vs carbon absorption.

	Vertical Wells	Horizontal Wells
Carbon Adsorption	\$25,629,846	\$27,332,727
Fume Incineration	\$10,269,006	\$11,970,594

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